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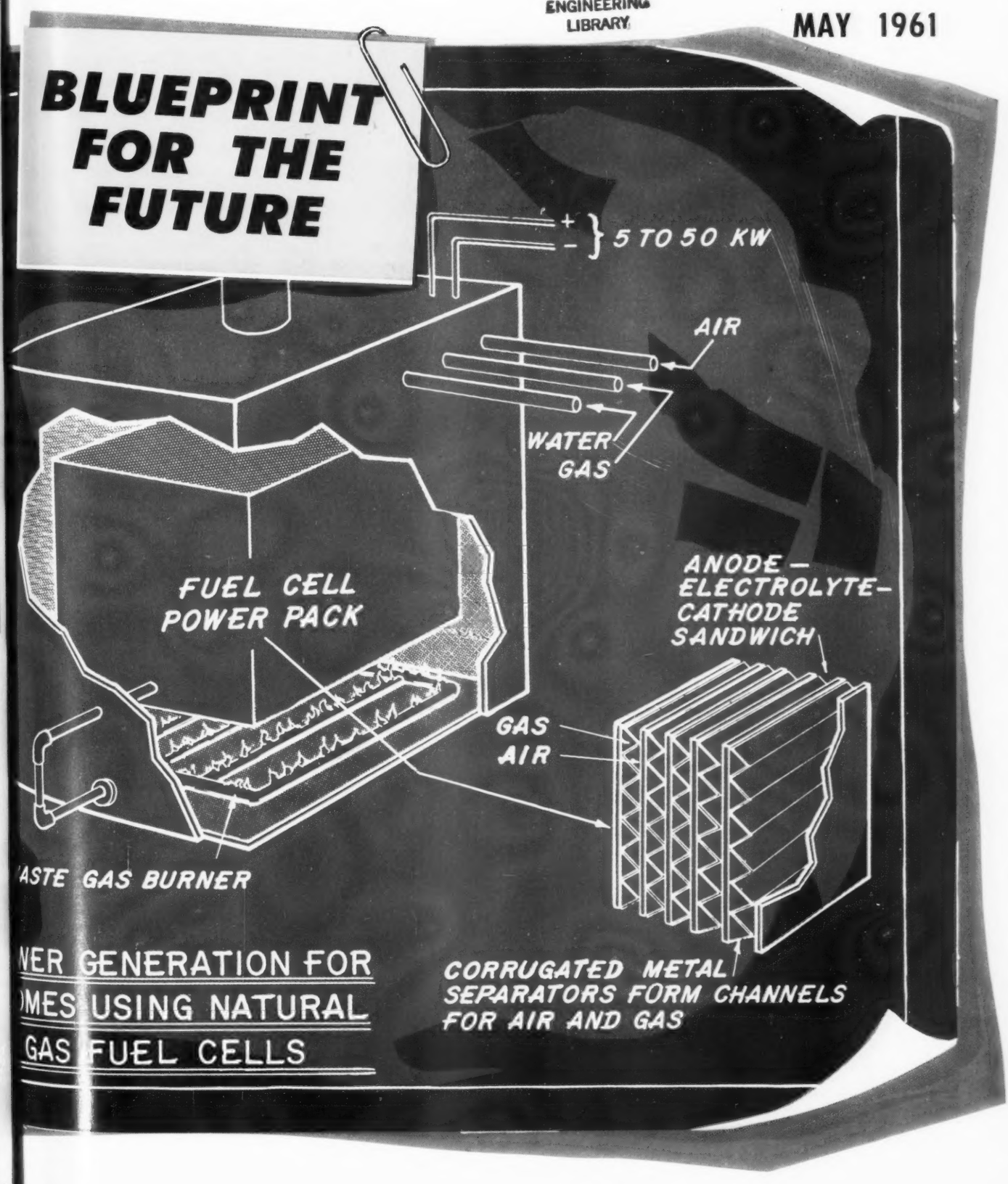

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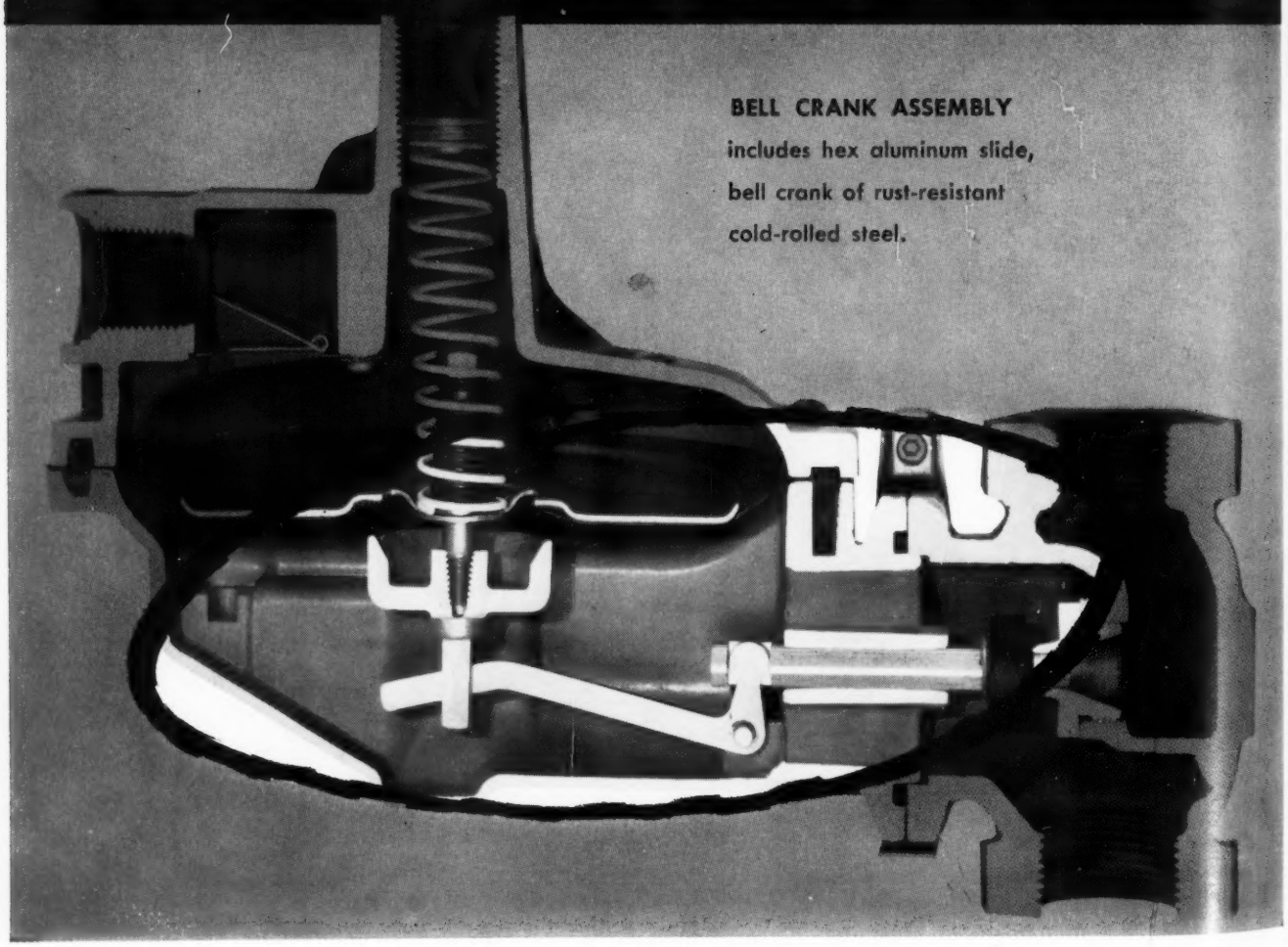

PILOT LIGHTS

The Black Box Awaits

You may not see an all-gas, single energy source, black box residence in operation in 1961 (although one might spring up to prove us wrong), but the odds are that you'll see them in the future.

Researchers at the Institute of Gas Technology are intently pursuing the natural gas fuel cell with an eye toward developing what is popularly known as a "black box"—into which you put natural gas and air and take out electrical power on the other side.

Think what a tremendous development this will be for tomorrow's homeowner . . . no unsightly electrical poles on streets and alleys and parkways, no dangling and hazardous wires, no need for electrical meters, etc., etc.

Think, also, what it will mean to tomorrow's gas company . . . or "Energas" company, perhaps . . . a utility operation based on gas service that is the basis for both heating, cooling, and electric power requirements of the home.

Progress is being made toward that "black box." A report on recent developments begins on page 24, this issue.

And for the uninitiated, on page 29 is a rather comprehensive "Guide to Fuel Cell Technology." You'll probably want to clip and file this for daily reference . . . especially in today's fast-moving technological world.

Seven Years, Still Itching

'Twas almost seven years ago the Supreme Court, ruling on the now famous (or infamous) Phillips Case . . . declaring that the FPC must regulate natural gas producers. In the ensuing period, thousands upon thousands of ideas have been expressed on the subject. There have been hearings, court cases, remands, more hearings, some settlements, and a lot of dissatisfaction. But not much of a solution to the problem has been uncovered yet. Area pricing may be an answer . . . maybe. Some of the problems, and some suggested solutions, are offered in a discussion of the price muddle featured in this month's "Fuel for Thought" forum. Recommended reading . . . turn to page 9.

American Gas Journal

THE MAGAZINE OF GAS DISTRIBUTION

VOLUME 188 — MAY 1961 — NUMBER 5

In This Issue

Special Report

Natural Gas Fuel Cells for Power Generation 24

Tomorrow's homes will need only one energy source — in the form of gas — to make possible single source heat and electricity.

Guide to Fuel Cell Technology 29

Comprehensive appendix gives definitions of terminology, details most important fuel cell types and their characteristics.

FREE — For your files, an extra copy of this 2-part article. Check No. 30 on reader service card.

Management & Operations

What's Ahead for Price Regulation of Natural Gas? 9

On a subject of vital interest to utilities, this month's "fuel for thought" article points out factors that need consideration in determining regulated prices and suggests some realistic approaches to the problem.

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Fun With Approximations 36

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M C F

NEWS HILITES OF THE INDUSTRY

New look for the FPC, asked by the Kennedy administration, will depend on how Congress reacts to the presidential proposals. In a mid-April message to Congress, the President asked for : 1) An increase from five to seven commissioners; 2) Authority to appoint the FPC chairman who would serve "at the will of the President; 3) Authority for the FPC to exempt independent producers selling less than 2-billion cu ft annually; 4) Authority for the FPC to exempt pipeline company applications concerned with enlargement, extension, or replacement of existing facilities for the benefit of existing customers, and 5) Requirements that would make pipeline companies put rate increases into escrow, pending FPC disposition of the increases.

Addition of two members to the commission ostensibly would be to permit establishment of separate gas and electric panels; such a move would enable the administration to "pack" the commission with members of its own choice or party (in June, the administration will be able to fill a third post under the present setup).

Independence of the FPC would be threatened by the proposal to appoint a chairman "at the will of the President." It is known that the chief executive is unhappy with the prospect of Jerome K. Kuykendall continuing to serve as chairman . . . and rather than make an issue of it, has asked Congress to step in with new legislation.

Strings are attached to the producer exemption request . . . the President did not ask for legislation for direct exemption . . . but merely to give FPC the power to do so at its discretion. No suggestions on how to regulate the "big producers" were made, either.

Hearings on the "Enchilada Inch" will resume May 10 before the California Public Utilities Commission. The three-day hearing will be devoted to presentation, by the applicants for the 1600-mile Texas-to-Mexico-to-Southern California line, of direct evidence in support of the project. The following week, on May 17, opponents of the proposal, led by Southern California and Southern Counties Gas Companies, will begin cross-examination.

Executed . . . but not necessarily dead. That's the story of "indefinite" price-escalation clauses in all new interstate natural gas rate contracts. Since April 3, the FPC has been rejecting such clauses . . . last of three rate-increase devices to face the firing squad. The three are the favored-nation clause, some types of price escalation, and price redetermination. In the future, independent producers and pipelines must negotiate firm rates for long periods when drawing up contracts. Still allowed (if the FPC approves) are "definite" escalation provisions.

First gas space heating sales campaign in Chicago in 20 years is being launched by The Peoples Gas Light and Coke Co. It will also be the utility's largest single-theme promotion since 1941. Theme of the campaign is fact that for the first time since 1946, gas space heating is available immediately for all Chicago homes, apartment buildings, institutions, and businesses.

Breakthrough . . . Chrysler Corporation announced a new development in its gas turbine program that would provide rapid acceleration and engine braking characteristics long sought in the turbine field. A new variable nozzle system for directing hot gases against turbine blades was described by Chrysler as a major scientific breakthrough. An engine equipped with the new system generates 140 hp and weighs only 450 lb.

New president of GAMA is William G. Hamilton, Jr., president of American Meter Co. Also named at the Boca Raton, Florida, meeting of the Gas Appliance Manufacturers Association were first vice president — J. F. Ray, vice president, sales, General Controls Co.; second vice president — Joseph J. Decker, president of the Plumbing and Heating Division, American Radiator and Standard Sanitary Corp., and treasurer — Robert C. LeMay, manager of contract sales, Selas Corporation of America.

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Continued from page 3.

MCF NEWS HILITES OF THE INDUSTRY

A Seminar on Industrial and Commercial Use of Gas Turbines — first of its kind conducted in the natural gas industry — is to be held in Houston June 15-16 under auspices of Southern Gas Association. Seminar follows closely recent publication of a report on a joint A.G.A.-SGA research project covering application of gas turbine to supply all energy requirements of a secondary school building including air conditioning and high frequency lighting. D. Dana Price, author of the report, "A New Look at New Schools" will make a detailed presentation on the secondary school turbine application.

Joint venture to develop a natural gas fuel cell has been announced by Northern Natural Gas Co. of Omaha and Houdry Process Corp. of Philadelphia. Research will be conducted at Houdry's Linwood, Pa., laboratories where fundamental fuel cell research has been in progress for some time. Goal of the two companies is to produce electricity right in homes and factories by using a fuel cell powered with natural gas which will supply all of the energy requirements of a household or business at costs significantly less than current sources. Critical part of the fuel cell development is the catalyst and Houdry is expected to contribute greatly in this area because of its 30 years experience in catalysis.

New Jersey Natural Gas Co. and its pipeline supplier, Texas Eastern Transmission Corp., plan a joint venture 23-mile, 10-in. supply line that will increase daily delivery capacity by 40,000,000 cu ft. The line, to cost $3,000,000 will enable New Jersey Natural to meet increasing demands for gas service in the fast-growing Monmouth-Ocean County metropolitan region, declared Dale B. Otto, company president.

Interstate gas transmission companies aren't privileged to determine who can serve industries in a given area, with or without the acquiescense of the local gas distributor, an FPC examiner has ruled. The ruling was directed at Southern Natural Gas Co., which proposed to provide interruptible gas service to two Savannah, Georgia, firms. The examiner, Robert M. Weston, said that this was FPC's prerogative, based on standards of the public interest directed to the consumers' protection and benefit.

United Fuel Gas Co., plans to install a new gas turbine-driven centrifugal gas compressor unit designed and developed by Solar Aircraft Co. on its Spencer, W. Va., pipeline compressor station. The compressor is driven by a 1100 hp Saturn T-1000 gas turbine engine that operates on fuel taken directly from the pipeline. Advantages expected include lower initial cost, greater reliability, and low cost maintenance. Compressor and engine together weigh only 9000 lb.

Century 21 Gas Exhibit, Inc. has been organized to direct the natural gas industry's participation in the world exposition to be held in Seattle in 1962. Organization followed endorsement by American Gas Association, and its approval of a $200,000 exposition program to be financed by gas companies throughout the nation. William P. Woods, president of Washington Natural Gas, heads the newly-formed corporation. Charles M. Sturkey, executive consultant of WNG, is vice president and managing director. Exposition will depict recent and potential advances of civilization and will be aimed at permitting visitors to "step into the next century."

All that glitters is not gold, the City of Moses Lake, Washington has found. Five years ago the community voted in favor of a municipally owned natural gas distribution system. Recently, the citizens of Moses Lake went to the polls and reversed that earlier decision by a 5 to 1 margin. After five years, they learned that municipal operations weren't up to par — service was poor, the number of customers fell far short of expectations, and cheap Federal government electric power was a powerful competitor for the city-owned gas system. Net effect — not even operating expenses were covered the first year; bond interest payments seemed unlikely and redemption of the bonds was out of the question. Solution: The system was sold to an investor-owned company, Cascade Natural Gas Corp. The agreement provides money to pay both interest and principal on $1,200,000 par value of the bonds, and the citizens are assured of good gas service.

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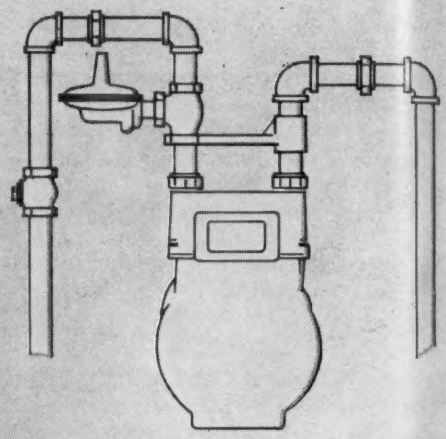

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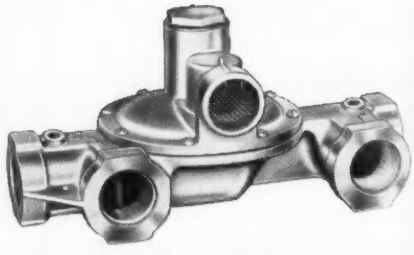
Save up to $4.00 per meter installation

Compare the installations above. Count the number of fittings. Check the difference in piping. Consider the time it takes to install both units. See for yourself how to save $4.00 (on parts alone) with Fisher S-254, a compact meter bar regulator, tailor-made for household demands.

Consider also these specifications: Compact S-254 has aluminum body and casings, for strength, easy handling, low shipping costs (weight 2¾ lbs.). It's rated at 250 CFH with 2 psi inlet pressure and 7″ W.C. outlet pressure. It handles inlet pressures up to 100 psi. Springs are available for reduced pressures from 3½″ W.C. to 18″ W.C. Both valve disc and orifice are renewable through inlet. S-254 has internal relief valve and large weather proof vent which provides full capacity relief. For complete information on the S-254 and the entire S-250 series, send for bulletin P-S250A. Fisher Governor Company, Marshalltown, Iowa. Plants in Woodstock, Ont., Rochester, England. Butterfly Valve Division: Continental Equipment Co., Coraopolis, Pa.



Type S-254 Meter Bar Body with internal relief valve, and pressure test connections for both inlet and outlet pressure. Constructed with meter couplings spaced 6″ center to center.

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S254 (with relief)	¾″ x 1″ x 1″ x 1″ ¾″ x ¾″ x ¾″ x 1″	¼″—⅜″	9″—12½″ W.C. 12″—18″ W.C.	

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Calendar

OF COMING EVENTS

May

3 PCGA accident prevention roundtable, Biltmore Hotel, Santa Barbara, California.

8-12 A.G.A. operating section distribution and production conference, Sheraton Hotel, Philadelphia, Pennsylvania.

14-18 National Fire Protection Association annual meeting, Detroit, Michigan.

15-17 A.G.A. mid-west regional gas sales conference, Edgewater Beach Hotel, Chicago, Illinois.

17-19 Pennsylvania Gas Association, annual meeting, Pocono Manor Inn, Pocono Manor, Pennsylvania.

25-26 Natural Gas & Petroleum Association of Canada, annual meeting, London, Ontario, Canada.

25-26 PCGA customer service conference, Jack Tar Hotel, San Francisco, California.

26-27 Florida Natural Gas Association, Americana Hotel, Bal Harbour, Florida.

June

5- 6 A.G.A. eastern regional gas sales conference, Pittsburgh Hilton Hotel, Pittsburgh, Pennsylvania.

6- 8 ISA summer instrument-automation conference and exhibit, Royal York Hotel, Toronto, Ontario, Canada.

20 NEGA operating division, Worcester Polytechnic Institute, Worcester, Massachusetts.

20-24 Canadian Gas Association, annual meeting, Banff Springs, Alberta, Canada.

21-23 NEGA measurement control and corrosion school, Worcester Polytechnic Institute.

26-28 American Society of Heating, Refrigerating & Air Conditioning Engineers, Inc., annual meeting, Denver Colorado.

26-27 Michigan Gas Association annual meeting, Grand Hotel, Mackinac Island, Michigan.

28-30 Second Joint Automatic Control Conference sponsored by ISA, AIChE, AIEE, ASME, IRE, University of Colorado, Boulder, Colorado.

August

28-30 Appalachian Gas Measurement Short Course, West Virginia University, Morgantown, West Virginia.

September

11-13 A.G.A. annual accident prevention conference, Statler Hilton Hotel, Dallas, Texas.

11-15 ISA fall instrument-automation conference and exhibit and ISA's 16th annual meeting, Los Angeles, California.

12-14 Mid-West Gas Association school and conference, Ames, Iowa.

13-15 PCGA annual convention, Coronado Hotel, Coronado, California.

18-19 Independent Natural Gas Association of America, annual membership meeting, Shamrock Hilton, Houston, Texas.

18-22 A.G.A. industrial gas school, Marriott Motor Hotel, Philadelphia, Pennsylvania.

20-22 Southeastern Gas Association, annual meeting, Roanoke, Virginia.

24-27 ASME Petroleum Mechanical Engineering Conference, Hotel Muehlebach, Kansas City, Missouri.

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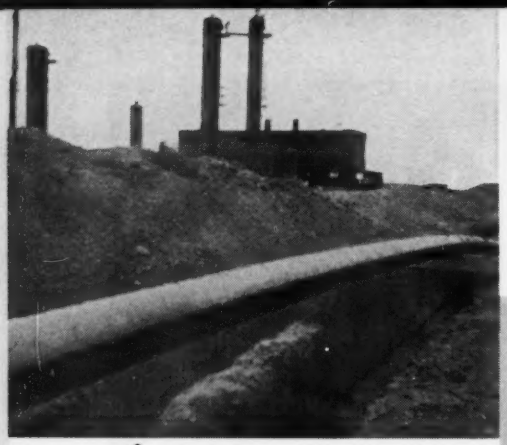

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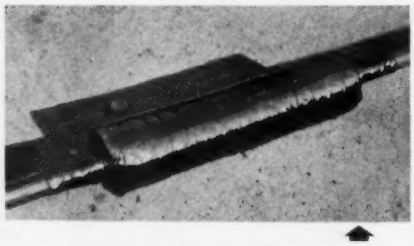

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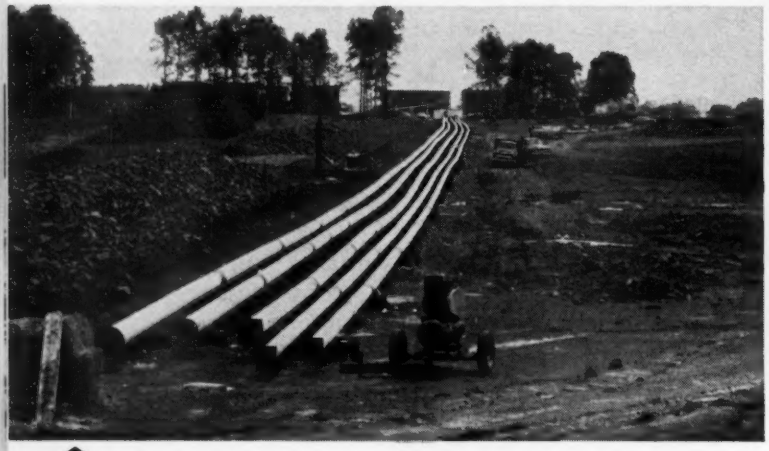

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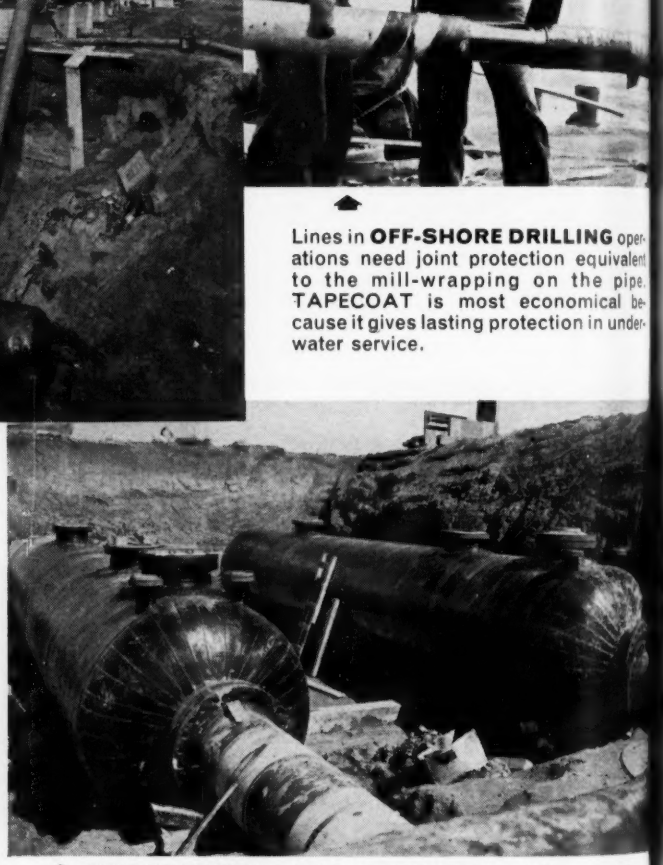
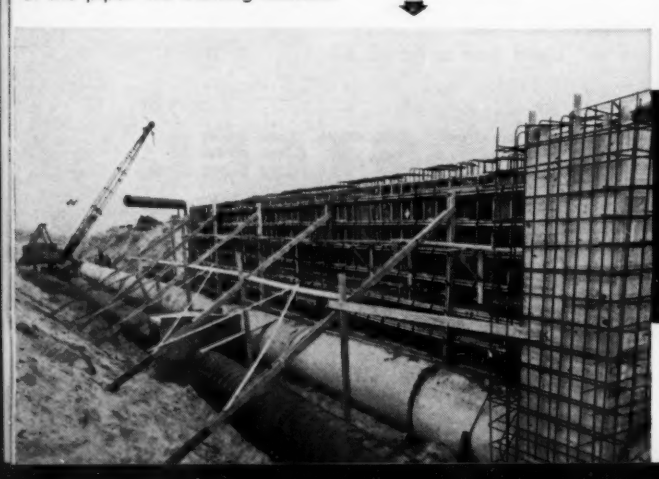


UNDERGROUND GAS STORAGE facilities can be "buried and forgotten" when protected by TAPECOAT. Note protection of tanks, pipe and pipe joints.

Lines buried in cinders in **RAILROAD YARDS** need the sure protection provided by TAPECOAT. There's a size for every purpose from 2" to 24" in width.



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ROUND TABLE

Monthly Forum on Fuel for Thought

What's Ahead For Natural Gas Field Price Regulation?

Robert E. Field, CPA, *Partner, Price Waterhouse & Company*

The future course of natural gas field price regulation by the Federal Power Commission remains uncertain despite the area price approach announced a few months ago by the Commission as an effort to break through the complexities of rate making in this area. Working rules for area pricing have not even been established and already its existence is threatened by the change in federal administration.

When President Kennedy fills the FPC post that becomes vacant in June, he will have appointed a majority of the members.* Will the newly constituted Commission continue the area approach in spite of harsh criticism by James K. Landis, the President's overseer of independent agencies?

The answer depends, in part, on the alternatives. What makes natural gas regulation so difficult? Why has the FPC adopted the area price approach? These points must be understood as background for developments that, undoubtedly will be taking place in the Commission, in Congress, and in the courts.

Producer Not a Public Utility

Much of the difficulty arises from overemphasis of cost as a means of determining fair price. In our philosophy of economics price regulation is justified only where competitive market forces are absent—*and this absence has not been established with regard to the price of natural gas.*

On the contrary, there are obvious competitive pressures from oil, coal, and alternative unregulated intrastate gas markets. A seller cannot expect to obtain more for his gas than its value simply because his costs are higher. Neither should the buyer expect to pay less than exchange value if costs are lower. The FPC cannot force the market to accept either extreme.

Although substantial price increases in recent years are pointed to as evidence of an absence of competition, the most obvious cause is the known increase in demand for gas. This increase in demand comes from new consumers who are still in a position to choose among the alternative sources of energy.

Cost has no place in regulated price determination except where no better evidence of exchange value, such as competitive price, is available. Cost has been validly used in connection with rate making for many years in situations where there is an exclusive market, where no evidence of value is available, and where there is a predictable relationship between service and costs. Thus it has been used more extensively in regulating gas, electric, water and communication facilities than for air and surface transport where there is no monopoly.

EDITOR'S NOTE

Nearly seven years have elapsed since the Supreme Court "ruled" that natural gas producers were to be regulated on the price they could charge for natural gas in the field. The ruling brought confusion and chaos to the industry. To most observers, the FPC has been able to accomplish little in bringing even a semblance of order from this chaos. Robert E. Field, CPA of New York and a partner in the national public accounting firm of Price Waterhouse & Co., has given special attention to the pricing problems of natural gas producers regulated by the FPC. In this discussion, he points out numerous factors that must be given consideration in determining regulated prices and suggests some realistic approaches to the problem.

Pros And Cons Of Area Pricing

Apparently the FPC is trying to accomplish by administrative means what it has been asking Congress to do for several years—to provide a standard for pricing natural gas as a commodity that would not require use of rate base or utility rate making principles, but which would enable the Commission to weigh the interest of the consumer (low prices) with the necessity of providing assurance of future gas supplies. *This concept assumes that it is necessary to find a fair price for the gas itself—not for each producer.*

The Landis report recognizes that rate making for natural gas producers is not analogous to that for electric power, gas transmission, and air and rail traffic. Somewhat inconsistently, it also dismisses the FPC's attempt to solve the problem by use of area prices because they substantially reject the rate base approach.

Unfortunately, the Landis report makes no suggestions for a method to take the place of the area approach, except by excusing minor producers from regulation. This one suggestion neither solves the problem of regulating the remaining producers nor is it necessarily practical. It is easy to conceive of a group of individuals arranging exploration and production efforts in a manner to enable each of several operating units to produce less than the critical volume and to escape regulation even though in total the volume of these individuals' operations might be significant.

The Landis report also objects to "fixed" area prices because they "come close to approximately maximum prices." The proposed area prices, in fact, are neither "fixed" nor do they approximate "current maximum prices" as alleged by the report. The area prices are only **guides**, subject to

*See "FPC" page 3, this issue, for details on President Kennedy's most recent recommendations for the FPC.

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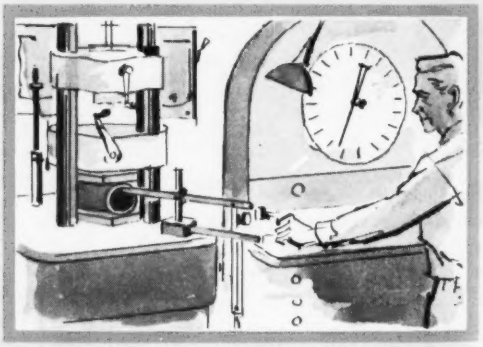

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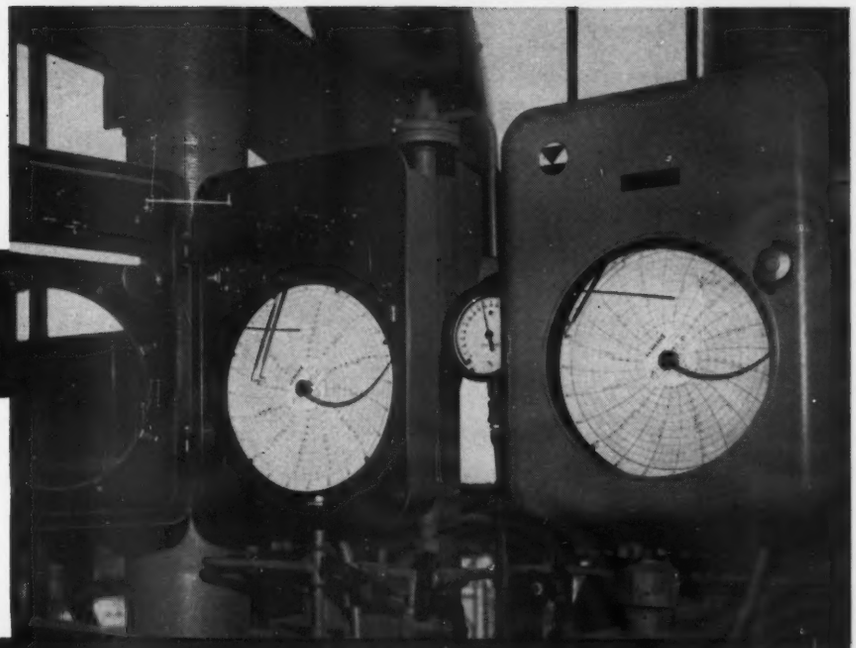
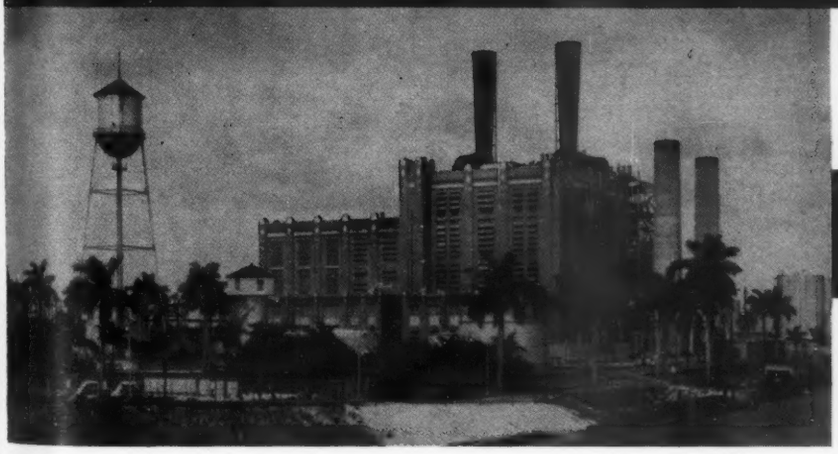


American Integrating Orifice Meters, in a duplex setting, measure gas for boiler at Ft. Lauderdale power plant. These meters are equipped with a fixed gear train to provide a direct reading in cubic feet of gas at base conditions.

AMERICAN® instrumentation solves measurement problem for Florida Power and Light Co.



Florida Power and Light's Ft. Lauderdale power plant. Two of five boilers use 45 million cubic feet of gas per day on an interruptible basis, can consume up to 60 million cubic feet daily.

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change in accordance with some eight factors suggested by the FPC and, at least for the present, have been established at two levels for each area. The lower of each of these pairs of prices, applicable to increases in price of gas already committed, is considerably less than the current prices offered for new gas by pipeline purchasers.

How Can Area Approach Be Applied

The FPC has stated the principal criteria for setting area price guides to be "financial requirements" and "cost information." It seems impossible to express these criteria except in terms of cost. Cost is not an appropriate criterion of fairness of price of a scarce natural resource such as natural gas, which has an intrinsic value entirely apart from that added by conversion to marketable condition. Apparently, any cost data obtained will be used only to show changes in financial requirements or exploration and production costs over a period of years, indicating the direction in which gas prices ought to be moving.

Perhaps the FPC had in mind presentations of a type common to other agencies—for example, ICC and CAB —which consider general cost trends in the industry, influence of competition, etc., all in the light of the value of service rendered. Industry-wide operating ratios might be included in these presentations because they do not depend upon a rate base, but there would be a problem of determining reasonable return in order to decide what margin above operating expenses is necessary to encourage optimum production.

Allocating Oil/Gas Costs

This brings us to one of the fundamental problems of rate making in this industry—*that of splitting joint costs equitably between the joint products, oil and gas.* Although economists might be able to determine a reasonable operating margin for the petroleum industry as a whole, can they determine what share belongs to gas and what share to oil? And what about the joint exploration and production costs that add up to the major portion of a producer's total costs?

This allocation problem has baffled both economists and accountants for many years. Without an equitable allocation of the incentive element of financial requirements, an artificial profit margin will be introduced. *For this reason alone, evidence of financial requirements and cost information should not be used as an absolute standard of the fairness of gas price.* Such evidence, however, split by means of a reasonable and consistent common denominator between gas and oil, might be taken as an indication of cost trends over a period of years; this might be useful as a supplement to better evidence of a fair market price.

The usual and most reasonable common denominator for energy fuels is Btu content—used by the Bureau of Mines, by engineers concerned with selection among alternative sources of energy, and by the FPC in the Phillips case. Although a barrel of oil contains about six times as many Btu's as an Mcf of gas, the Commission, in the Phillips case, gave the Btu content in oil a weighting of four to allow for products of crude oil that are used for purposes other than direct heat conversion, resulting in a 24 to 1 ratio.

If the FPC wishes to recognize the effect of factors other than direct heating ability by modifying the natural Btu relationship between gas and oil, it should make use of data not subject to regulation. The use of relative prices of crude oil and gas depends on the same type of circular reasoning condemned by the Commission in other applications because existing gas prices are being used in part to determine whether existing gas prices are proper.

A more reasonable method of modifying the natural Btu ratio of 6 to 1 can be obtained from a comparison of crude oil and residual fuel oil prices over a period of years and at various common pricing points. Neither of these products is price regulated but each contains about the same number of Btu's per barrel and, therefore, any differences in prices presumably reflect the additional value of crude oil products for which residual fuel oil could not be substituted. Residual fuel oil, on the other hand, is used directly for heating purposes and competes with natural gas on the 6 to 1 Btu basis.

To illustrate this method, let us assume that crude oil sells for $3 a barrel and residual fuel oil for $2 a barrel. Since crude apparently assumes 1½ times the importance of residual fuel oil in the eyes of the consumer, the natural 6 to 1 relationship can be converted to a modified ratio of 9 to 1 by multiplying the Btu content in a barrel of crude oil one and one-half times. Actually, a comparison of relative prices of these products over a period of years at comparable pricing points indicates that 10 to 1 is an appropriate modified ratio rather than the FPC's 24 to 1.

Even for the limited purpose of showing trends, cost data should be prepared on an industry-wide basis. Exploration costs that are part of a national or international program are relatable equally to all gas wherever produced. *In any event, the consumer is not interested in the area from which his gas comes, nor the cost of producing that gas, but only its worth to him.* Area differentials in the FPC price guide should be based on appropriate economic factors. For example, a producer in Pennsylvania supplying gas to the eastern market might receive more for his gas than one in Texas supplying the same market. Proximity to market makes his gas more valuable in the field even though the burner tip price is the same.

Exchange Value Determines Fair Price

Even as evidence of confiscation value (which is the producer's ultimate constitutional defense) cost is an unsatisfactory measure unless the property seized, or substantially equivalent property, has recently been traded. Natural gas deposits have considerable latent value unrelated to the cost of finding them and producing the gas.

A simple illustration points out the absurdity of using cost as evidence of confiscation. In many cases a gas property is owned by several different working interests whose costs would be the same only in rare and accidental cases. It would be ridiculous to use a different level of price as the point at which confiscation begins for each of the several working interests simply because each had a different cost of production. *Obviously, the commodity is of equal value to each, and its value depends on the price at which it can be sold.*

A fair market price of gas is more likely to be found by consideration of market factors than costs of production. Competition from alternative fuels and intrastate markets can be used as evidence. Also, some approximation of a fair price for gas in the field could be obtained by deducting gas transmission costs from comparative prices of equivalent quantities of heating oil or coal in the end market.

Although this method ignores significant factors bearing on gas prices, both favorable and unfavorable, such as cleanliness and possible interruption of service, it ought to have some validity as one indication of the exchange value of gas.

Until—and unless— the new area pricing policies become better defined and more established, the prudent producer will continue to present evidence of his own costs on the best available basis but will also develop, preferably in conjunction with others, evidence of: (a) changes in financial requirements consisting of trends in industry-wide costs over a period of years, and (b) exchange values as the appropriate standard of justness and reasonableness and as a measure of confiscation.

* * *

Men At Work

● John C. **Bolender** has joined North Shore Gas Company of Waukegan, Ill., as manager of operation.

J. C. Bolender

J. H. Motz

● **J. H. Motz** has been named a vice president of Atlanta Gas Light Co.; he will also continue as secretary. **J. W. Lea,** former manager of the commercial sales department, has been named general sales manager. Assisting him will be **Marion R. Kays Jr.,** sales manager, who just recently joined Atlanta Gas Light. **Orbie Bostick** has been promoted to manager of commercial and industrial sales; succeeding him as chief industrial engineer is **F. Richmond Chadwick Jr.,** former industrial engineer for company's Macon division. **G. F. Edwards** has been named manager of Atlanta division of Atlanta Gas Light. He was formerly residential sales manager of the Atlanta suburban offices.

● **Joe Boyd,** member of Oklahoma Natural Gas Co.'s sales department air conditioning and heating department in Oklahoma City, has been promoted to supervisor and director of company's air conditioning and heating activities in Oklahoma City district.

● **Harry J. Schmidt,** former assistant manager, general accounting department for Philadelphia Gas Works, has been named manager, general accounting department. In conjunction with Schmidt's appointment, **Robert L. Barrett** and **William W. Henry** have been promoted to assistants to the manager of general accounting.

● Recent personnel changes at Peoples Natural Gas Co. of Pittsburgh include promotion of **Henry N. Robb** to staff assistant, budgets, **John V. Whitacre,** formerly in the treasury department, succeeds Robb as property records supervisor. **Robert G. Bashore,** formerly with the industrial development department of the Reading Co. in Philadelphia, has been appointed assistant manager of area development for Peoples.

● **Remick McDowell,** who became chairman of Peoples Gas Light and Coke Co. March 1 has been elected chairman of the boards of directors of a number of subsidiaries of Peoples Gas. McDowell succeeds **Eskil I. Bjork** who remains as a director. The subsidiaries are: Natural Gas Pipeline Co. of America, Natural Gas Storage Co. of Illinois, Peoples Production Co., Texoma Production Co., Kimswick Development Co. and Union Hill Gas Storage Co.

● **Andrew J. Sordoni Jr.,** president of A. J. Sordoni Construction Co., has been elected a director of the United Gas Improvement Co.

● **R. B. Paquette,** operation analysis engineer, has been appointed to fill the newly-created position of executive engineer at Peoples Gas Light and Coke Co. **John R. Dunston,** supervisory engineer, engineering, has been appointed to succeed Paquette as operating analysis engineer.

● Southern California Gas Co. has announced a major reorganization and expansion of its sales department that calls for creation of 2 new manager positions and an executive assistant post. Named to executive assistant is **J. C. Abram,** who is currently rate engineer in the finance and rate department. **C. T. Dierker** will take over new position of manager of sales promotion. He is currently general staff supervisor of non-residential sales. **W. A. Wilson** will fill the other new manager position as manager of division sales.

● **George H. Clayton** has been named to fill the newly-created post of director, new construction marketing. Formerly sales manager of Southern Counties' San Gabriel Valley division, Clayton will be responsible for contacts with major builders who maintain offices in Los Angeles metropolitan area and will coordinate promotional programs with these builders. **W. D. Simonsen** succeeds Clayton in San Gabriel Valley division.

● **Max R. Llewellyn,** manager of Arizona Public Service Co.'s gas and electric operations, has been named a vice president by utility's board of directors.

● **C. L. Neaves** has been named administrative assistant to Joe C. Darrow, Lone Star Gas Co.'s vice president in charge of distribution. Neaves succeeds recently-retired **F. L. Richardson.** A graduate of Texas A&M College, Neaves joined Lone Star in 1947 as a cadet engineer, became district engineer at Dallas in 1950 and has been distribution engineer for firm's Dallas Div. since 1952. He is also a contributing editor to *American Gas Journal.*

● **Ivan C. Wyden,** former field supervisor with Bureau of Applied Social Research at Columbia University, has been named assistant marketing research analyst of American Gas Association Bureau of Statistics.

● **J. Theodore Wolfe** has been elected chairman of the board of Baltimore Gas and Electric Co. In this capacity he will serve as company's chief executive. **Charles P. Crane,** former chairman of the board, will continue as director and chairman of the executive committee. **Austin E. Penn** has been elected president, succeeding Wolfe in that position.

● Laclede Gas Co. has named **Francis R. Leonard** assistant vice president for industrial relations. He has been manager of industrial relations for the firm since 1959.

James B. Douglas, 82, former claims and insurance executive of Philadelphia Gas Works Div. of United Gas Improvement Co. over a period of 54 years, died recently. He has been in retirement since 1955.

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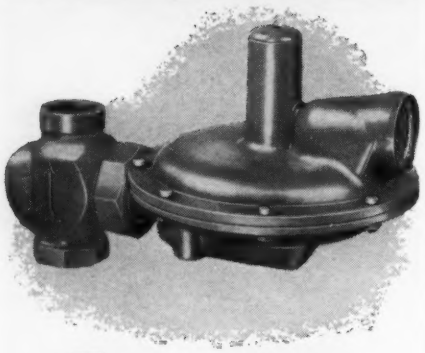

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Men at Work

● **John Emery,** assistant general superintendent of Rio Grande Valley Gas Co., has been promoted to general superintendent.

John Emery

W. B. Wood

● Rio Grande Valley Gas Co. has announced election of three new officers. **William B.Wood,** general superintendent of the company since 1957, has been elected vice president in charge of distribution and transmission operations; **John T. Ashford,** manager of production, has been elected vice president in charge of production and gas development; and **Robert T. McMinn,** assistant treasurer of the company, has been elected assistant treasurer and assistant secretary.

● **Willard G. Wiegel,** treasurer and vice president in charge of personnel for Lone Star Gas Co., retired April 1 after almost 33 years of continuous service.

● The Houston Corporation and its affiliates have announced the following promotions and transfers within the company: **S. L. Windham,** formerly general superintendent of pipelines, has been appointed general manager of distribution properties for Houston Corp. **Eldon Rolfe,** chief engineer for Houston Texas Gas and Oil Corp., will assume responsibilities of general superintendent of pipelines for Coastal Transmission Corp. and Houston Texas Gas and Oil Corp. **Jim Hoss,** chief engineer for Coastal will become chief engineer for Houston Texas Gas as well.

● **Lorne S. (Larry) Waddel** has been named to the newly-created post of manager of communications by the American Gas Association. **Edward J. Reardon,** formerly city editor of The Evening News, Perth Amboy, N. J., succeeds him as manager of press relations.

● **Charles R. Woods** has joined Honolulu Gas Co. as staff engineer. Previously, Woods has headed his own building and general contracting firm in Seattle.

● **Bob Lee Corbell** has been appointed residential air conditioning sales supervisor for Houston Natural Gas System. He was formerly residential heating and air conditioning representative in Houston Natural's Houston-Pasadena service area. In his new capacity, he will supervise the residential an dsmall commercial air conditioning sales program through Texas Gulf Coast service area.

● Iowa Electric Light and Power Co. has appointed **Peter Stover** director of purchasing and stores, and **Don Hunt** as chief mechanical engineer. Stove succeeds **Marvin Wright,** who is retiring, and Hunt assumes Stover's former responsibilities. Hunt will be responsible for design and construction of power plants, gas pipelines, and gas distribution systems.

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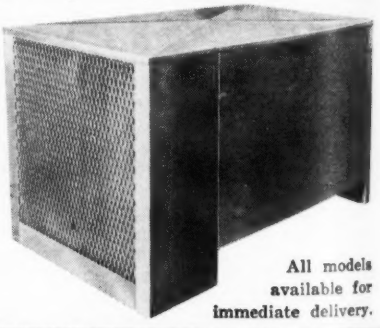

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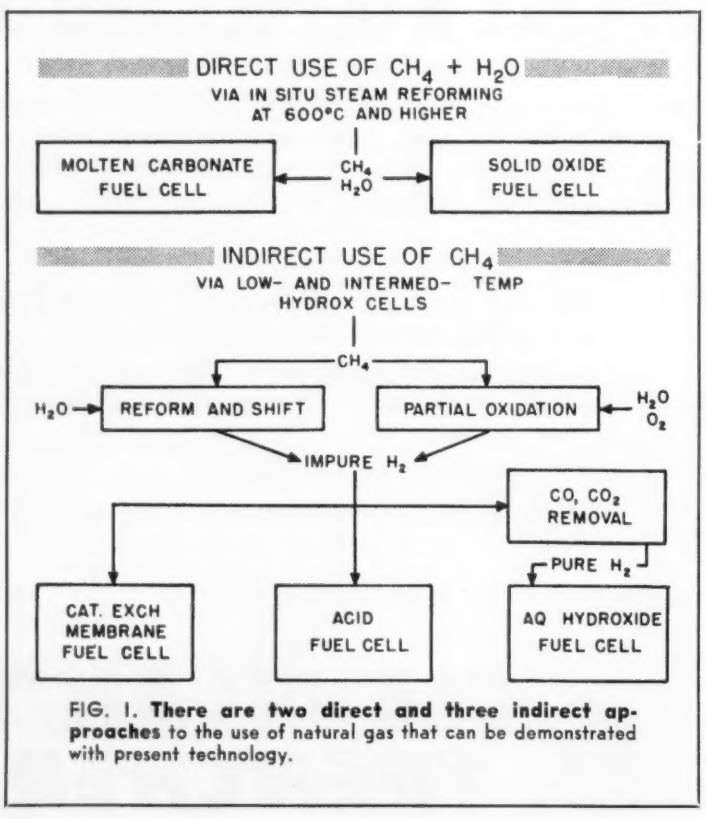


FIG. 1. **There are two direct and three indirect approaches** to the use of natural gas that can be demonstrated with present technology.

FUEL CELLS *have been rapidly becoming more important in the plans of a number of industries, as well as in military planning. At present, over 60 industrial and government fuel cell projects are known, expending millions of dollars annually.*

An ever increasing number of types of fuel cells are in development to meet specialized future needs of the electrical, electronic and battery industries, the automotive industry, and military and space agencies. In addition, fuel cell work related to production of electricity from coal has been done, and another energy-oriented group, the petroleum industry, has some of the most important fuel cell research and development programs of the present.

The gas industry is also presently active, through American Gas Association-PAR Plan sponsorship of research on natural gas fuel cells at the Institute of Gas Technology. This report reviews current progress of this project and related engineering-economic studies, which are directed primarily toward the development of fuel cell power packs for dwellings, to supply all or most of the home needs for electricity.

To aid in understanding the ideas and evaluations developed herein, an appendix on the essentials of fuel cell technology is included following this report. This includes definitions of terms, an explanation of the functions of cell components, a classification of the many types of cells, and a brief summary of the most significant industrial fuel cell development programs that are known.

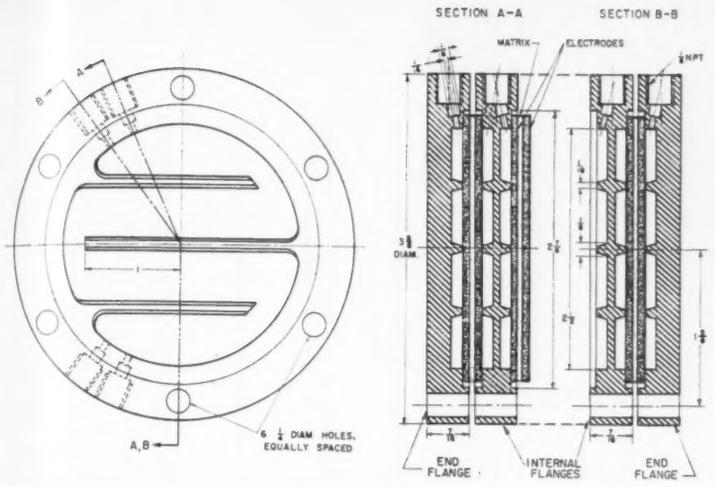


FIG. 2. **Flanges for experimental fuel cells and batteries** were constructed with fingers to provide contacting pressure and distribute gas over electrode surfaces.

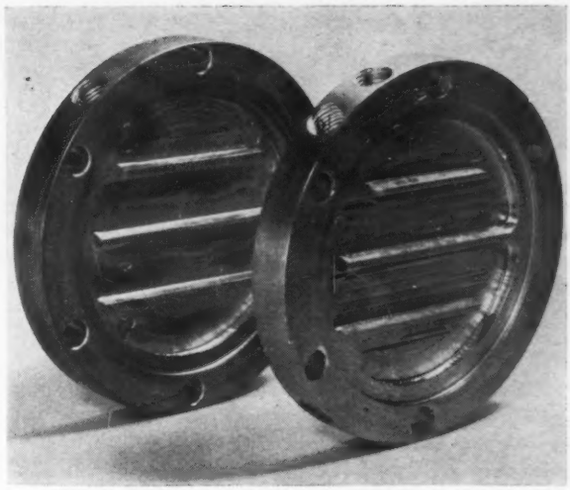


FIG. 3. **These are the fuel cell flanges** used in research studies on high-temperature natural gas fuel cells.

If natural gas can be used as the energy source, fuel cell power packs may be economic for supplying all or most of the electricity requirements of a home.

In many areas of the country, a unit of energy in the form of gas costs the residential consumer only one-sixth to one-eighth as much as a unit of energy in the form of electricity.[2,15] It seems likely that this basic cost advantage will be large enough to offset the unavoidable additional costs in converting energy to electricity in a multiplicity of small installations. This should be possible primarily because of the relatively high efficiency of low unit cost of small fuel cell systems.

The low cost of transporting and distributing energy to the consumer's home in the form of gas would then make possible the convenience and versatility of a single source of heat and electrical energy in an all-gas home.

Possible approaches to development Of natural gas power packs

At this time, the **direct electrochemical oxidation of gaseous methane** does not appear practical because of its low reactivity in fuel cells of all kinds. But there are two demonstrable approaches for overcoming this problem; these are outlined in Fig. 1.

Even though methane alone will not oxidize rapidly enough, it is still possible to use it "directly" in a high-temperature fuel cell, if steam is present. Since tests have shown that bone-dry methane does not react, but that steam-methane mixtures do, it is assumed that steam reforming occurs on the anode surface, and that the observed current is due primarily to electrochemical oxidation of hydrogen produced as a reactive intermediate, at cell temperatures in the range for catalytic steam reforming and carbon monoxide shift.[9]

Two types of electrolytes have been used in these high-temperature cells: *molten carbonate mixtures,* and *solid ionic oxides.* The carbonates have received the most attention in prior work, by far, and a large amount of useful technology has been published within the last ten years (see Fig. C of Appendix). Largely because of this available body of information, and demonstrated ability to use methane if fed with steam, the molten carbonate cell appears to be a prime candidate for development in a natural gas appliance. Most of the prior work with carbonates has been with hydrogen and carbon monoxide fuels and comparatively few data have been obtained with methane plus steam. Therefore, a thorough study of the effects of variables is necessary. Further, anode materials probably can be improved in catalytic activity, since no real effort has ever been made to do this.

Despite its dominance of the high-temperature fuel cell field, the carbonate cell has inherent drawbacks. Molten carbonates are corrosive. They have low viscosities, thus are fugitive and will tend to creep away eventually over contacting surfaces. Further, sodium, lithium and potassium carbonates will decompose at operating temperatures, forming carbon dioxide, and alkali metal oxides which have low conductivity.

To prevent decomposition, a partial pressure of carbon dioxide equal to or greater than the decomposition pressure of carbon dioxide equal to or greater than the decomposition pressure must be present at all times at the anode and cathode, and other exposed surfaces of the electrolyte. In addition, enough carbon dioxide must be available at the cathode so that carbonate ions may be formed by the reactions:

$$O_2 + 4 \text{ electrons} \rightarrow 2O^{=}$$
$$2CO_2 + 2O^{=} \rightarrow 2CO_3^{=}$$

which show that two volumes of carbon dioxide must be present for every volume of oxygen utilized. The carbonate ion then migrates across the electrolyte to the anode, where it becomes available as a source of oxygen, to oxidize the fuel with a release of electrons to the external circuit (Fig. B of Appendix). Thus, oxygen is not transported directly in this type of cell; carbon dioxide must be provided as an oxygen carrier.

In theory, a solid oxide cell should avoid the above difficulties. Solid electrolytes would be noncorrosive, easy to contain, and thermally stable. Oxygen would be transferred in the form of oxide ions, not carbonate ions, and no carbon dioxide additions to the oxidant are required.

Although the theory of solid oxide fuel cells has been known for some time, no satisfactory experimental work has been done. Some attempts were made about 25 years ago, with carbon as the fuel and with oxide electrolytes that were far from the best choices according to modern solid state knowledge.[7,8] Further, no effort was made to engineer solid oxide cells with practical shapes for high conductivities. In summary, the solid oxide cell is not nearly as advanced as the carbonate cell, but holds more promise if new

theories lead to the choice of better electrolytes, and if engineering efforts to make practical cells are successful.

Fig. 1 also shows the **indirect approach to the utilization of methane,** in which methane is first converted to a hydrogen-rich stream in external apparatus. Two well-known processes are indicated: *steam reforming* and *partial oxidation*. Both produce impure hydrogen, containing concentrations of carbon monoxide and dioxide that will react with hydroxide electrolytes to form carbonates. In aqueous solution near ambient temperature, carbonates are poorly conductive. Further, carbonates can precipitate within electrode pores, covering up active reaction sites. This rules out the use of a number of fuel cells presently known that use aqueous KOH as electrolyte (Union Carbide, Allis-Chalmers, Electro-Optical, Leesona-Bacon). Of course, removal of carbon oxides is technically feasible but expensive, and the advantages of hydroxide cells would probably have to be very great to justify hydrogen purification costs.

It seems more reasonable to employ fuel cells that are not affected by the presence of carbon oxides, and these are the cells in which hydrogen ions carry the charge through the electrolyte. Certain acids may be used, in principle, as well as cation exchange resin membranes. The latter, in particular, have received much attention in recent years, first at General Electric and more recently at Ionics, Inc.

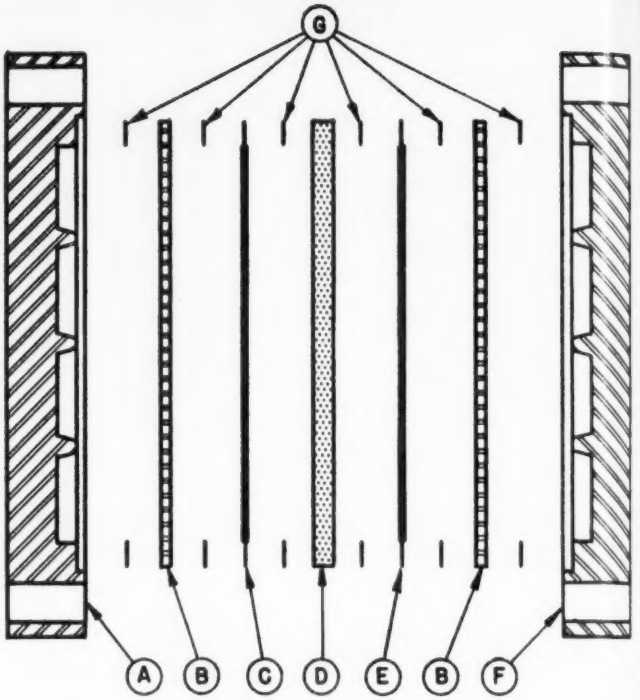
The original **ion exchange fuel cell** invention is credited to General Electric scientists, for hydrogen and oxygen as fuel and oxidant.[18] This led eventually to the development of a fully-engineered 200-watt portable generator for the Marine Corps, perhaps the most workable application of any kind of fuel cell. Indications are that investment costs are much higher than for any other fuel cell;[1] thus, the approach may not be economically attractive in a non-military application. Further, there are technical drawbacks connected with control of membrane moisture content, destruction of the plastic electrolyte sheets due to local overheating, and with scaleup beyond a fairly small size.

The Ionics, Inc., fuel cell also employs ion exchange membranes, but uses bromine oxidant which can be regenerated with air in external apparatus.[20] Advantages are gained in fuel cell current and power density, but a regeneration system is required, with attendant investment cost and maintenance.

In the case of **acid fuel cells,** little is known beyond recent work at the Kettering Foundation on pasty mixtures of orthophosphoric acid with powdered inerts.[14] Higher current densities were observed than with cation exchange membranes. The approach should avoid the above-mentioned drawbacks related to the use of resinous electrolytes. Much work will be needed to establish the value of acid cells for power packs.

In evaluating the five demonstrable approaches to a home power pack, it might appear attractive to develop a miniature steam reformer and CO shift unit, and utilize the product gas in a battery of cation exchange cells. This would probably be inherently expensive, second only to a **hydroxide fuel cell** system requiring hydrogen purification. Although investment costs of such a system would certainly be high, largely due to the catalysts employed in cation exchange cells, there may be very little research remaining to be done to develop this device. Steam reforming and partial oxidation processes have been commercialized, and cation exchange cells have been brought to a relatively advanced stage of development. Thus, this approach seems likely to be technically certain, but economically unattractive. Expenditure of more research effort may lead to only incremental improvements in costs.

More attractive as a research and development venture is the direct use of methane plus steam in a high-temperature cell. Conversion of methane to hydrogen within the cell



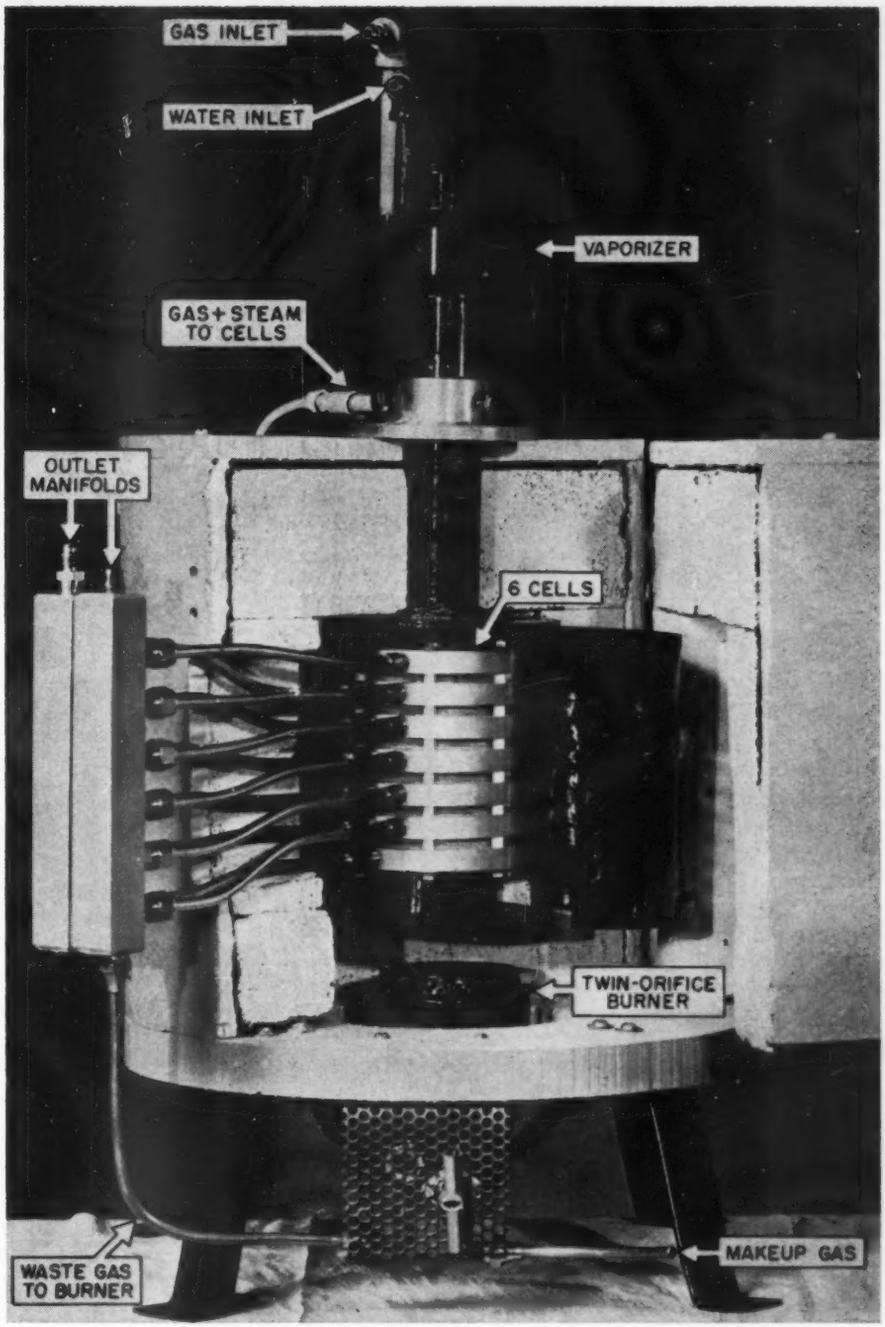
A ANODE FLANGE
B PERFORATED PLATE, 2 3/4" OD × 1/32" THICK
C POROUS NICKEL ANODE (CLEVITE, SONOTONE), COINED ON BOTH SIDES, 2 3/4" OD × 35 MIL THICK
D MgO MATRIX, 2 3/4" OD × 1/8" THICK
E POROUS SILVER CATHODE (CLEVITE), COINED ON BOTH SIDES, 2 3/4" OD × 35 MIL THICK
F CATHODE FLANGE
G SILVER GASKET, 2 3/4" OD × 2 1/2" ID × 0.01" THICK

obviates the need for external reforming equipment, and it is likely that investment cost for a molten carbonate battery will be lower than that for a cation exchange battery of the same capacity. Further, the possible overall thermal efficiency with internal reforming is greater, since the heat requirements for the reforming reaction are approximately equal to the heat release due to cell inefficiencies.

A power pack for home installation using high-temperature fuel cells would provide for the addition of steam to the natural gas feed, the addition of flue gas (as a source of CO_2) to the air feed in the case of molten carbonate cells, and underfiring with waste gas from the cells to compensate for normal heat losses. There are several possibilities for utilizing the waste heat from the fuel cells, in conventional appliance functions presently used in the home.

It is recognized, of course, that high operating temperature is not compatible with the on-off, low load factor operation typical of home electrical utilization. Storage batteries would most likely be employed to raise the load factor and smooth the power demand so the high-temperature fuel cells could operate essentially continuously.

Instead of providing a large power pack capable of meeting peak loads of, say, 10 kilowatts, a one kw unit operating continuously together with battery storage would be designed. The investment in storage batteries would be less than the fuel cell capacity they would supplant. Also, it is an advantage to supply electricity from storage batteries, which have flat operating characteristics (essentially constant voltage at any current density). All fuel cells have comparatively steep voltage-current curves, which require



◗ FIG. 4. **High-temperature molten-carbonate cells** were made leaktight with silver gaskets.

◗ FIG. 5. **Six-cell battery of natural gas fuel cells,** mounted in a gas-fired furnace, was used to demonstrate principles of operation.

special voltage control techniques and additional investment cost.

It would probably be desirable to convert direct current to alternating current, for residential service, although this may not prove to be essential. There are several semiconductor devices presently available for this purpose, which operate with efficiencies in excess of 85 percent, and which have investment costs that are likely to be attractive.

In the case of low-temperature fuel cells operating on high hydrogen content, reformed methane, it is technically feasible to operate on an on-off, low load factor basis. Even so, a storage battery system would probably be mandatory to cut down on the investment in these inherently expensive cells, most of which would not be in use except during moments of peak demand.

In summary, the high-temperature fuel cell approach, integrated with waste heat utilization and an electrical storage battery system, is an attractive development venture. Molten carbonate cells can be used at first, because much is known about their characteristics. Solid oxide cells are most desirable, in principle, and may eventually supplant the carbonate cells if research presently in progress is successful. The power pack development can be carried out so solid oxide and molten carbonate cells can be interchanged at any stage with little additional effort. The low-temperature fuel cell approach, using cation exchange cells integrated with a miniature steam reformer and shift unit and an electrical storage battery system is probably uneconomic, but careful cost studies should be made to verify this. Also, since much of the cost is involved in the cation exchange cells, the feasibility of developing lower cost acid cells to replace them should be explored.

Progress on carbonate cells in 1960 at IGT

The project was initiated in March, 1960, and single-cell experimental work was begun in the early summer with porous magnesia matrices prepared by a method used by previous investigators.[17] Improvements in matrix prepara-

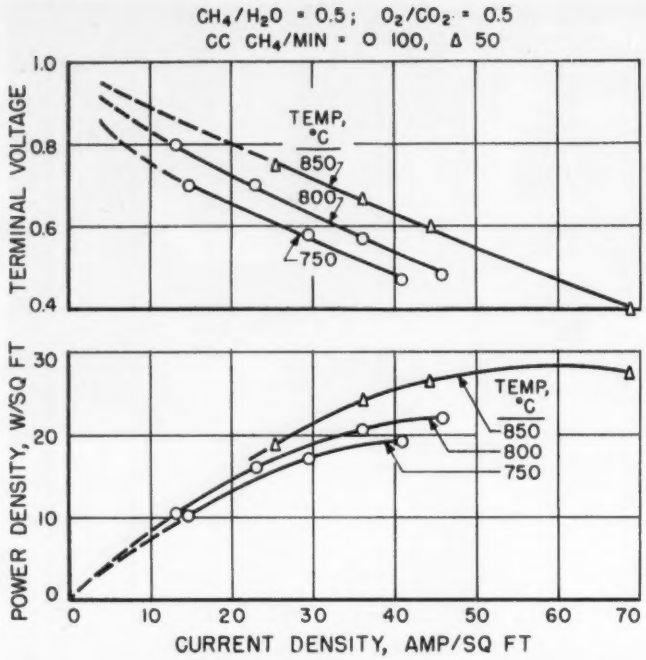


FIG. 6. **Data obtained on molten-carbonate cells** at IGT indicate current and power densities that can be obtained at practical operating voltages of 0.5 to 0.75.

tion techniques were made with the aid of the Armour Research Foundation, Ceramics Research Division.

Several nickel anode materials were tested and compared. Porous nickel battery plaques with embedded nickel gauzes (about 80 percent porosity, 10-micron mean pore opening, manufactured by Clevite, and by Sonotone), had adequate structural strength at temperatures as high as 920 C, and showed catalytic activity similar to powdered nickel anodes.[9] Porous silver plaques fabricated in the same manner by Clevite, with embedded silver gauzes, were satisfactory as cathodes. Also tested were cathodes formed from layers of 80-mesh silver gauze.

A cell was designed (Fig. 2 and 3) that gives good contacting and gas distribution by means of pressure fingers. The edges of the electrodes were coined, and silver gaskets were employed to eliminate leakage of gases at the cell periphery (Fig. 4).

Six cells were combined into a research battery and used to demonstrate operation with methane-steam feed, and to test new component ideas.[5] The six-cell battery was housed in a gas-fired furnace (Fig. 5) equipped for underfiring with waste gas from the cells.

Polarization curves (volts, versus current density in amperes per sq ft of electrode area) and power density curves (power density in watts per sq ft, versus current density) are shown in Fig. 6 for single cells. Methane flow rates in leak-tight cells were as low as 50 cc/min; about 3 cc/min is the stoichiometric requirement for generation of 50 amp/sq ft.

It can be seen that an increase in cell temperature from 750 to 850 C results in a considerable improvement in cell performance. Within 0.5 to 0.75 volts, a typical power pack operating range in most fuel cell studies, the power density was as high as 28 watts per sq ft, at 850 C. For a battery with a half-inch cell thickness (Fig. 3), this leads to a maximum power/volume ratio of about 650 watts per cu ft. Smaller cell thicknesses and therefore higher power/volume ratios would be expected in prototype batteries.

Progress on solid oxide cells

One of the early objectives of the project was to search for alternate electrolytes that would avoid the various drawbacks of molten carbonates. It was most important to eliminate the need for introducing carbon dioxide with the oxidant. A study of the literature indicated that solid ionic oxides might be useful. Results of this study, based on modern knowledge of solid state structure, are given briefly in the Appendix.

There are several practical requirements before a solid oxide cell can be developed. The cell should have a high current density to minimize battery size for a given duty. Therefore, the rate of diffusion of oxygen ions through the electrolyte must be high. This can be accomplished by forming a thin layer of electrolyte so that the oxygen ion concentration difference across the electrolyte per unit of thickness is large, and by choosing solid oxides with structures that permit high rates of diffusion. Furthermore, only oxygen ions should diffuse through the oxide, so the oxide layer should not contain pores or cracks which would permit passage of gaseous fuels or oxygen. The oxide electrolyte must also be adherent to the electrodes to give good contact, and inert to the fuels and oxidants so it will not change during operation of the cell.

Experimental work was begun at IGT by surveying candidate oxide solid solutions by x-ray powder diffraction, and by testing ground and polished disks of stabilized zirconia in fuel cells. It was recognized that practical oxide cells require oxide films on the order of one mil in thickness, and that some specialized coating technique must be used for this purpose. Accordingly, the Ceramics Research Division of Armour Research Foundation was consulted and plans were made to test flame spraying, "solution" and "slurry" ceramics, vapor deposition, pressing, and other methods, to achieve very thin coherent oxide films with the proper crystal structure. This work was begun in January 1961.

Another oxide film technique that shows promise is electron beam vaporization (Alloyd Corp., Cambridge, Mass.). Nickel anodes were coated with a layer of ZrO_2-CaO solid solution about 1/30 mil thick by this technique, and the fluorite structure was obtained after the vaporization. Thus, it appears that several thin film techniques have promise.

Research program

In 1961, the program of research and development of high-temperature methane fuel cells will involve five experimental areas.

With molten carbonate cells,

1) single-cell tests will be conducted on research cells to develop better electrodes, and electrolyte preparation methods, and to define effects of variables, and

2) design and construction of a 100-watt prototype battery is planned.

With solid oxide cells,

1) a number of promising techniques for preparing thin membranes of electrolytes will be studied by the Ceramics Division of Armour Research Foundation, and

2) single-cell tests will be conducted at IGT to evaluate cell components and the effects of variables.

A fifth area of study concerns a search for promising solid oxide electrolytes, a basic study conducted at the University of Miami under a *Grant-in-Aid*.

In addition, engineering-economic studies are planned, to develop estimates of manufacturing and other costs. Also, it is hoped to include a technical and economic evaluation of the alternative approach involving a low-temperature cell (such as ion exchange), and conversion of methane to hydrogen in separate apparatus.

Acknowledgment

This work was sponsored by the American Gas Association through its PAR (Promotion-Advertising-Research) Plan. This report was presented at the A.G.A. Research and Utilization Conference, Cleveland, Ohio, April 5, 1961.

APPENDIX

GUIDE TO FUEL CELL TECHNOLOGY

Terminology

A fuel cell is an electrolytic cell that converts the chemical energy of a continuously fed, fluid, fuel-oxidant system directly into electrical energy. Conventional gaseous and liquid fuels, and air or oxygen, are normally used as reactants.

By contrast, ordinary cells and storage batteries, like the Leclanche cell and lead-acid battery, employ solid reductants (fuels) and solid oxidants, such as zinc and manganese dioxide in the former, and lead and lead dioxide in the latter. Further, reductants and oxidants are not continuously fed.

A **battery** of fuel cells or ordinary cells is comprised of more than one cell, connected electrically. In the case of a **fuel cell** battery, the cells fed with fuel and/or oxidant either individually or in series. If both fuel and oxidant are fluid, the battery may also be fed **cocurrently** or **countercurrently.**

A **power pack** of fuel cells is a completely engineered system, comprising a battery or batteries of cells, appropriate housing, insulation, conduits, controls for fluid flow, electricity, temperature, etc.

In fuel cells, chemical energy is converted directly to electrical energy without intermediate conversion to heat, as occurs, for example, in **thermoelectric** and **thermionic** devices and in the conventional **steam turbogenerator** method of power generation. *Unlike these devices, the fuel cell is not a heat engine and, therefore, is not limited to the Carnot efficiency* (defined as $[T_1-T_2]/T_1$, where T_1 is temperature at which heat is absorbed and T_2 the temperature at which it is rejected). Instead, the maximum conversion is limited only to the free energy of the reaction, which for most conventional fuel-oxidant systems is only slightly less than the heat of reaction, or the fuel heating value in the case of oxygen as the oxidant. Fuel cell efficiencies are often expressed as "thermal efficiencies" or electrical work output/heat of reaction.

In one kind of fuel cell system, the fuel is regenerated from its oxidation product by application of heat in a vessel that is external to the cell; regenerated fuel is then returned to the cell. This system is usually called a **thermally regenerative fuel cell.** In this instance, the efficiency of the combination of fuel cell and regenerator is limited to the Carnot efficiency, although the fuel cell itself is not, since the overall combined process is a conversion of heat to electrical energy.

Photochemically regenerative fuel cells represent another approach, wherein the fuel and oxidant are regenerated from the oxidation product by the action of light photons.

Chemically regenerative fuel cells (so-called "redox" cells) are also known, wherein the regeneration step is accomplished by a chemical reaction. Certain fuel cells can also be regenerated electrically, as are conventional storage batteries and cells.

Some cells combine characteristics usually associated with fuel cells, and those of conventional electrolytic cells. Such combinations are still generally referred to as "fuel cells". For example, the zinc-oxygen cell has a solid, consumable anode or "fuel (zinc) as in conventional cells or batteries, but with oxygen (air) fed continuously to an inert cathode (as in a fuel cell). The sodium amalgam cell also has an oxygen (air) cathode, but uses solid sodium as the fuel. Thus, a wide variety of electrolytic systems generating electricity have been dubbed fuel cells, making it difficult at this time to establish precise definitions of terms.

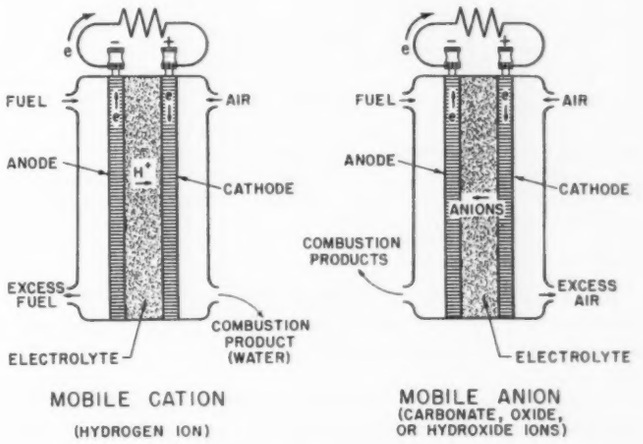


FIG. A. **Fuel cell electrolyte** may conduct current via mobile cations or anions. Present fuel cell technology includes one mobile cation and three mobile anions.

Most Important Fuel Cell Types And Their Characteristics

1. **Components of a fuel cell using conventional fuels.** All fuel cells must have the three essentials of an electrolytic cell — *anode* (fuel electrode), *cathode* (oxidant electrode), and the intervening *electrolyte* — making up a sandwich, together with means for contacting the fluid fuel or oxidant with its respective electrode (Fig. A).

For illustrative purposes, consider a fuel cell with gaseous fuel and oxidant, and inert electrodes. Anode and cathode "rooms" must be provided to permit the gases to pass across the faces of porous, "diffusion" electrodes. Gas diffuses from one side of such an electrode, and electrolyte from the other. The electrochemical reactions take place at interfaces and surfaces in and on the electrode.

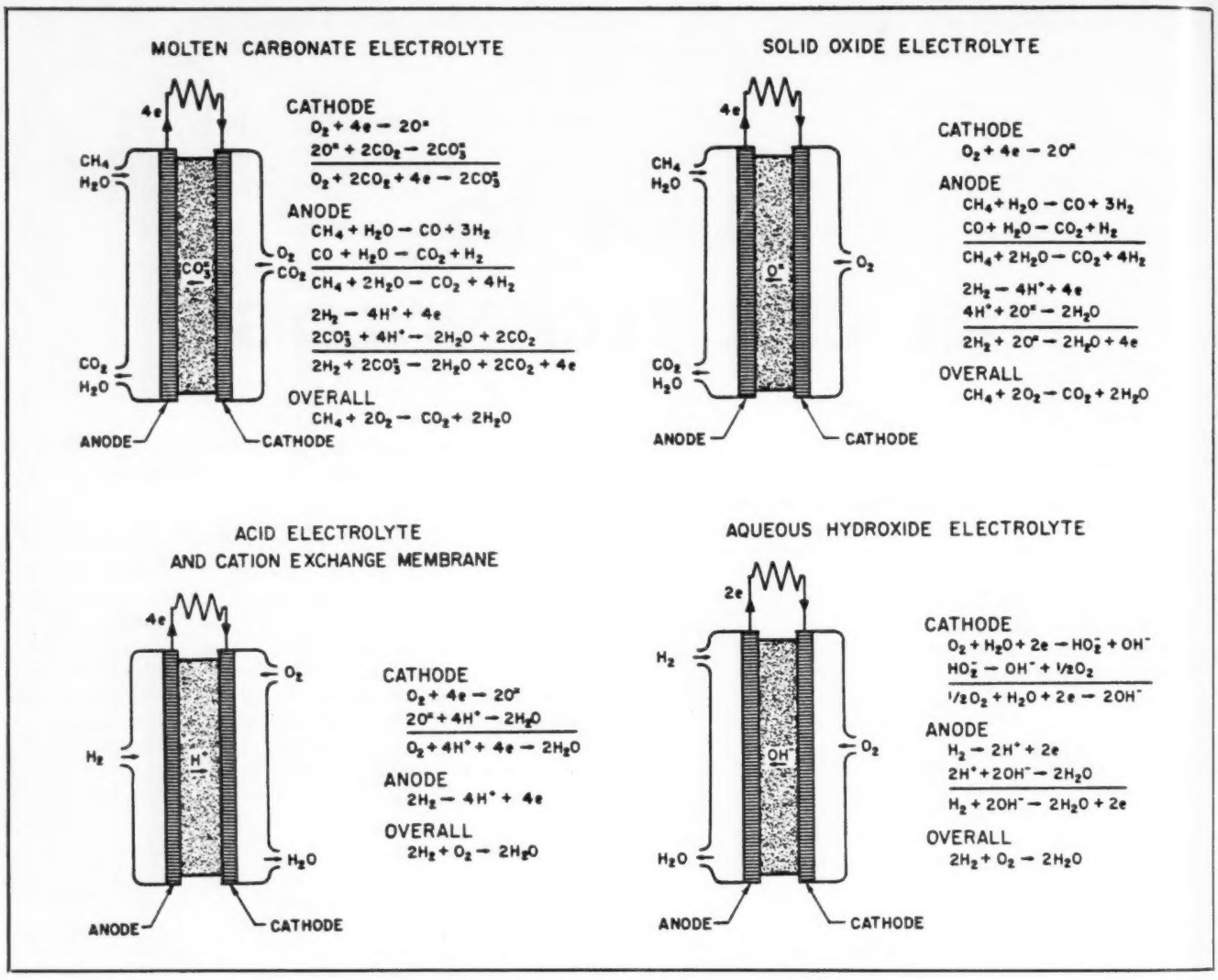


FIG. B. **Major fuel cell concepts** that may be considered for systems to generate power from natural gas are shown in four illustrations above.

The purpose of the electrodes is to catalyze the electrode reactions, and to conduct electrons away from the cell (in the case of the anode), and toward the cell (in the case of the cathode).

The electrolyte must be nonconductive to electrons, to prevent internal circuiting, so that electrons will flow from anode to cathode through the external load, doing work. The electrolyte must, however, be conductive to ions (charged chemical species) to complete the circuit.

2. **Major types of fuel cells.** Since there are only two kinds of ions — anions or negative ions, and cations or positive ions — there are basically two types of fuel cells. Fig. A shows these, together with the functions of the components.

In practice, there are known to be three kinds of anion-mobile cells — hydroxide, oxide and carbonate — but only one kind of cation-mobile cell, the hydrogen ion cell. Fig. B shows these four major fuel cell concepts, with the overall chemical reactions involved when oxygen is the oxidant, and hydrogen the fuel.

In the case of the carbonate and oxide cells, both of which are operated at high temperatures, it is possible to generate hydrogen inside the cell on the anode surface from natural gas (methane), by steam reforming and shift reactions. In the case of the hydroxide and hydrogen ion cells, operating temperatures are too low for methane to react catalytically with steam.

All four cells shown in Fig. B have to be considered for utilization in a power pack that consumes natural gas. The high-temperature carbonate and oxide cells can handle methane if steam is present in the anode room, and it is technically feasible to convert methane in external vessels to hydrogen streams suitable for the low-temperature hydroxide and hydrogen ion cells. In practice, relatively pure hydrogen is a necessity for only the hydroxide cell, to avoid carbonation of the electrolyte.

3. **Fundamentals of the solid oxide cell.** According to present theories of solid state chemistry, certain oxides will conduct oxygen ions (and only oxygen ions) over crystal lattice defects, specifically oxygen ion vacancies. The kind of ion that is mobile depends on the structure of the solid and on the temperature. On the basis of studies carried out to date, it appears that only the negative ions are mobile in solids having the CaF_2 or fluorite structure. This structure may be visualized as a lattice made up of metal atoms at the corners of a cube, and at the centers of the faces of the cube. Nonmetal atoms are at the corners of a smaller cube within the one bounded by the metal atoms.

If one adds an oxide like CaO to ZrO_2, the fluorite lattice will be observed within certain limits of composition. In this case, the ZrO_2 is referred to as the "host" oxide, and the CaO as the "mixing" oxide. In the fluorite lattice, the calcium atoms randomly replace the zirconium atoms. But,

a calcium atom brings with it only one oxygen atom, instead of the two that a zirconium atom requires. This means that there will be one oxygen vacancy for each calcium atom that is introduced. If oxygen ions are then provided at one surface of an oxide layer, by means of a fuel cell cathode, migration of oxygen ions can take place through the vacancies in the oxide crystal lattice.

Oxides other than CaO may be used as mixing oxides; MgO is another divalent example, and Y_2O_3, Sc_2O_3, and Nd_2O_3 are trivalent examples. In the latter, two atoms of the trivalent metal are required to produce one vacancy. In any case, oxygen atom vacancies are produced only if the mixing oxide has a lower valence than that of zirconium (+ 4). Other host oxides which could give the fluorite lattice with mixing oxides are HfO_2, UO_2, and ThO_2.

Since useful solid solutions must conduct only oxygen ions and not cations or electrons, many solids that contain polyvalent ions must be ruled out of consideration since they become semiconductors at high temperatures. Unfortunately, earlier experimental work on solid oxide cells included many such mixtures.

Since only the oxygen ions conduct current, measurements of electrical conductivity for solid oxides give useful information on the rate of passage of oxygen ions. These measurements have been published[22] for the composition 15 mole percent CaO, 85 mole percent ZrO_2. It was shown that the rate of migration of oxygen ions through the crystal lattice depended on the oxygen concentration difference between the two sides of the oxide layers, and on a constant which depends on the temperature, thus obeying Fick's law. These studies were carried out over a temperature region which is of interest for fuel cell applications.

From conductivity and diffusion measurements one can calculate the limiting current density for a given thickness of oxide, and given temperature, assuming that

1) oxygen moves only through vacancies in the fluorite lattice,

2) that all lattice vacancies are filled at the cathode-electrolyte interface, and

3) that all vacancies are empty at the anode-electrolyte interface.

For example, to attain 100 ma/sq cm (approximately 93 amp/sq ft) at 727 C, a layer no thicker than 1/30 mil is required. Diffusion rate increases with temperature, so at 1000 C the same limiting current density is predicted with a layer as thick as ¾ mil. Since the rate of diffusion is inversely proportional to thickness, doubling the thickness would cut the current passage in half. Of course, limitations in electrode performance or in achieving close contact of electrodes and electrolyte could lead to lower values in operating fuel cells.

Summary of Related Fuel Cell Development Programs

1. **Major fuel cell developments with gaseous fuels.** Industrial fuel cell research has led to two types of hydroxide cells with:

1) Carbon electrodes (Union Carbide[23]), and

2) Metal electrodes (Electro-Optical Systems,[24] Allis-Chalmers,[4] Leesona-Bacon[6]) using aqueous solutions of KOH as electrolyte.

In addition, a hydroxide cell using a paste of hydroxide mixtures at intermediate temperatures has been studied,[14] and hydroxide ion exchange membranes have been used.[19,25]

In hydrogen ion cells, most industrial activity has been with hydrogen ion exchange membranes (General Electric,[18] Ionics, Inc.[20]). Also, phosphoric acid has been under study as an electrolyte at intermediate temperatures.[14]

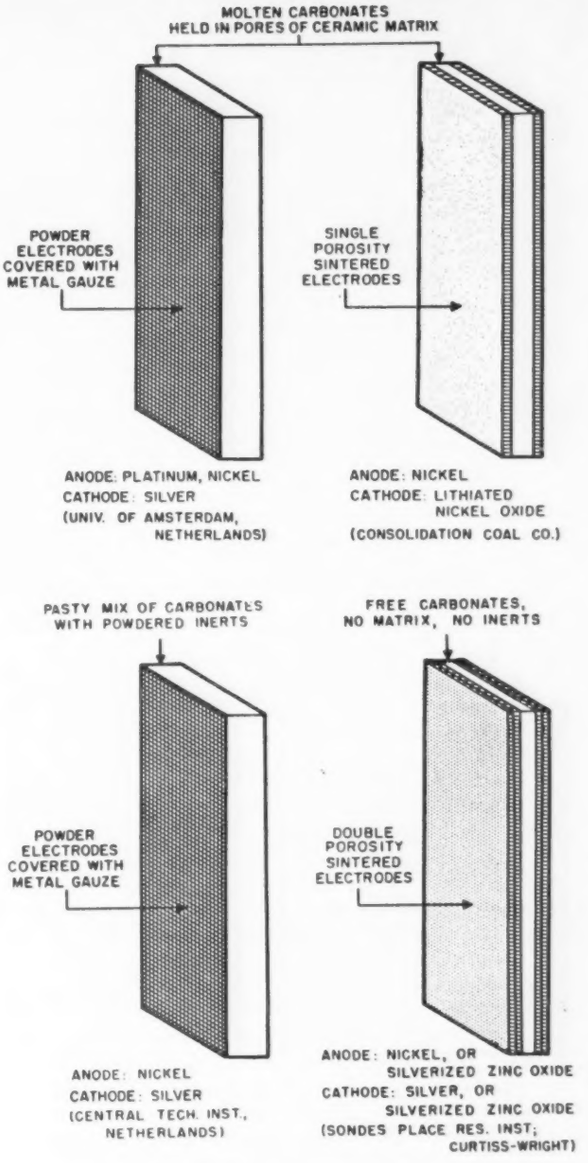

MOLTEN CARBONATES HELD IN PORES OF CERAMIC MATRIX
POWDER ELECTRODES COVERED WITH METAL GAUZE
SINGLE POROSITY SINTERED ELECTRODES
ANODE: PLATINUM, NICKEL
CATHODE: SILVER
(UNIV. OF AMSTERDAM, NETHERLANDS)
ANODE: NICKEL
CATHODE: LITHIATED NICKEL OXIDE
(CONSOLIDATION COAL CO.)
PASTY MIX OF CARBONATES WITH POWDERED INERTS
FREE CARBONATES, NO MATRIX, NO INERTS
POWDER ELECTRODES COVERED WITH METAL GAUZE
DOUBLE POROSITY SINTERED ELECTRODES
ANODE: NICKEL
CATHODE: SILVER
(CENTRAL TECH. INST., NETHERLANDS)
ANODE: NICKEL, OR SILVERIZED ZINC OXIDE
CATHODE: SILVER, OR SILVERIZED ZINC OXIDE
(SONDES PLACE RES. INST; CURTISS-WRIGHT)

FIG. C. **Several molten-carbonate cells** have been under study. At least four types are known.

Carbonate cells have variations also, as shown in Fig. C, with:

1) Molten electrolyte held in porous ceramic matrices,[9,17]

2) Plastic mixtures of molten electrolyte and inert filler,[10] and

3) Free molten electrolyte.[11,13]

In the latter case only, dual-porosity electrodes are needed.

2. **Long-range fuel cell concepts for methane.** There are two schemes recently announced that are not being developed for methane, but which might conceivably be applied if substantial advances in technology are made. Fig. D shows the soluble-reactant or "dissolved-fuel" cell idea which is under investigation by Esso[3] and by Monsanto[26] in the United States, and by Prof. Justi[21] in Germany. Very interesting results have been obtained with fuels such as methyl alcohol and hydrazine dissolved in aqueous electrolytes and contacted with nonporous, nondiffusion anodes.

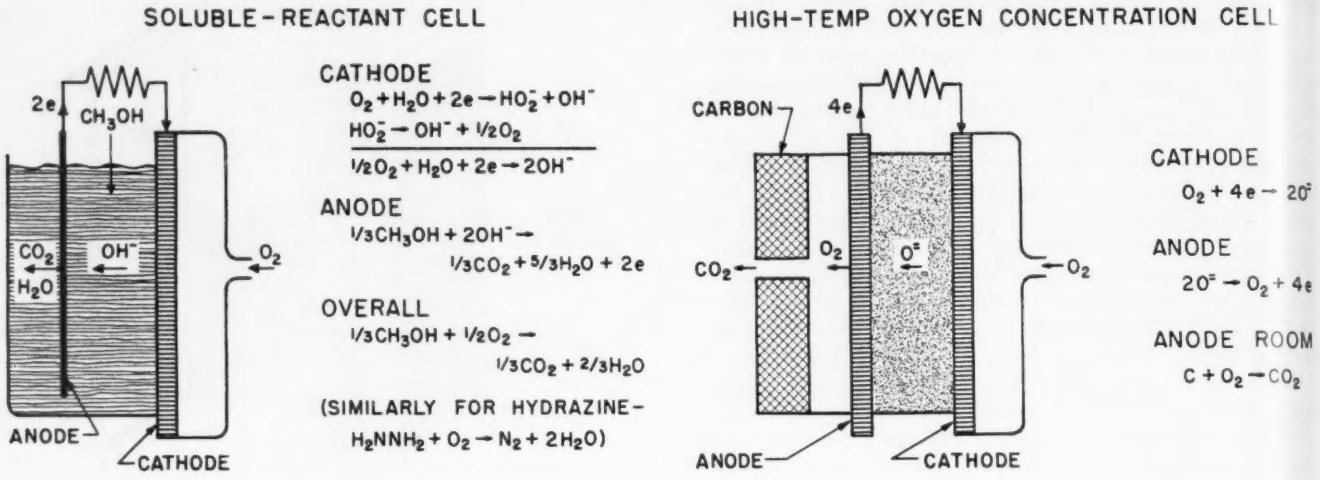


FIG. D. **These fuel cell concepts** may have future application with natural gas.

More active catalytic techniques will probably be needed before feasibility with dissolved methane can be shown.

The other long-range concept is the high-temperature oxygen concentration cell that Westinghouse is studying, with carbon as fuel (Fig. D). The components of this cell are very similar to those of any high-temperature fuel cell, but the fuel is oxidized in the anode room, and not on the anode surface. As practiced by Westinghouse, the concept seems to have most applicability to solid fuels such as coal, for central power generation. It is not known how useful the idea might be for natural gas.

There is a third approach (not shown) that might be applicable to methane: the thermally regenerative cell concept. At present, MSA Research Corp.,[12] and Thompson-Ramo-Wooldridge[16] are studying cells of this type as a means of converting heat from nuclear sources to electricity. The concept can be applied to any source of heat; in the case of natural gas it would be necessary to develop a regenerator that would combust gas and utilize the heat economically for the regeneration reaction. Present work on these cells is with hydride systems, such as lithium hydride, in which the overall reactions are:

$$\text{Generation:} \quad 2Li + H_2 \rightarrow 2LiH$$
$$\text{Regeneration:} \quad 2LiH + \text{heat} \rightarrow 2Li + H_2$$

In the regeneration step, both lithium and hydrogen must be recovered and returned to the cell. A more attractive scheme might be to utilize oxide systems. Air could be the oxidant instead of hydrogen, and the regenerated oxygen need not be recovered.

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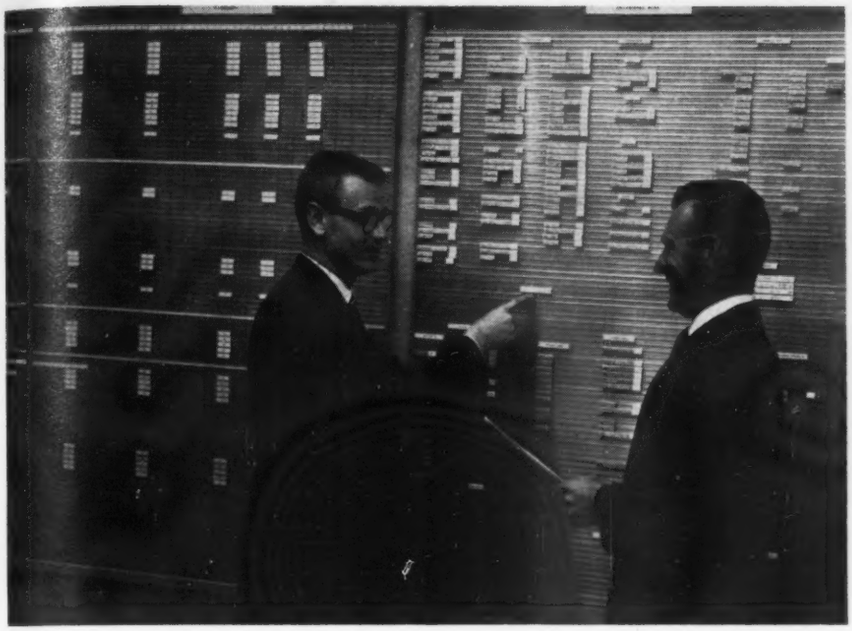
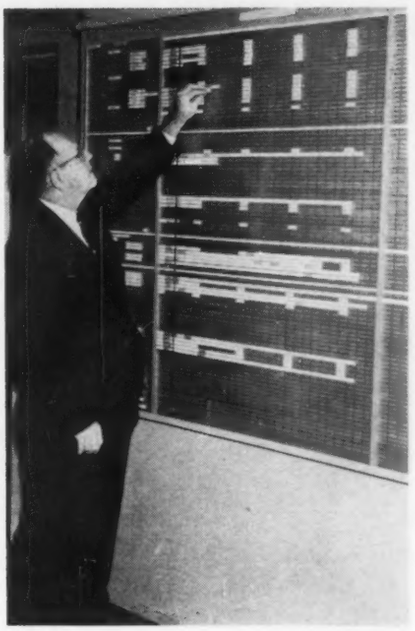


Checking Status of a Job. The author, Dick Smith, left, and assistant supervisor Harry Forr take a quick look at the planning board. Board gives fast over-all view of street work.



Posting A Job. Planning board is kept current by special assistant Allan Rich, seen posting a job newly-assigned to a crew on the street. Unassigned jobs, kept on a separate section of board, are posted when they become assigned.

What's Happening Where?

Visual Scheduling Panel Streamlines Construction, Maintenance Work Planning

Richard J. Smith, *Special Assistant, Distribution Department*
Philadelphia Gas Works, Division of U.G.I., Philadelphia, Pennsylvania

How can you best schedule construction and maintenance activities to effectively handle intermittent peak work loads? At Philadelphia Gas Works, a new visual display panel is being used as a scheduling tool to graphically portray work being done and projects coming up.

The scheduling panel is the newest tool used by the *Work Planning and Scheduling Center,* the central agency for coordinating construction and maintenance activities of PGW's Distribution Department. The center was organized in late 1959 to set up and maintain a system for controlling and scheduling work loads.

Like most gas distribution utilities, PGW must be ready to satisfy the demands of many outside activities. These include:

- Builders, whose activities are influenced by the demand for new dwellings.
- Paving, water, and sewer construction activities of the city.
- Area redevelopment resulting from city planning.
- PGW's sales activities
- Planned maintenance work
- Emergency work

Work volume created by these activities does not stay on an even level. It comes about sporadically. Large variations in the work load resulting from these influences require control of means and methods necessary to complete the work on time.

This is where the Work Planning and Scheduling Center comes in. It coordinates and analyzes the information received pertaining to these many internal and external activities . . . to aid in effectively utilizing the manpower, materials, and equipment available to the Distribution Department.

No matter what section of Philadelphia one might visit, it is usually possible to find a street excavation protected by PGW barricades. How does PGW know when the next job should be started? Where will it be? Which gang will perform the work? What type of equipment will be used?

These are some of the many questions that must be answered each day by the center and its two top men — Lee Schlagel, supervisor of large main construction, and Russ Stauffer, supervisor of new business operations.

The Large and the Small

Each job varies in size from a single, 10-ft long, 1¼-in. house service to a new housing development such as "Morrell Village" that will eventually contain 2700 or more homes requiring the installation of approximately 135,000 ft of main and 94,000 ft of service pipe to supply gas to the area.

In the past, the supervisor had to base his decisions on his long experience, his "feel" of activity in addition to personal contact with customers, contractors, and builders on the street. He played it by ear.

Today, through the aid of the Work Planning and Scheduling Center, the supervisors are able to base their decisions on more firm information. Through the collection of historical information, trends can be discovered and presented for study and analysis.

Timing is a most important factor in effective planning and scheduling. We must always be sure to have each job completed by the date required by our customers. A gang must not be moved to a job, however, before it is physically ready because of the additional expense involved.

Information concerning the progress of contractor's and builder's activities is constantly being reported to the "Center" by each supervisor and his assistant supervisors through the use of a Pre-Construction Inspection Report. This report is set up on a "tickler file" system that assures periodic visits to each future job location. The status found on each visit is reported until the job site advances to the point where it is desirable to assign a distribution gang to install the pipe.

Besides coordinating the information collected by its department, the "Center" has set up and maintains liaison with sales, stores, engineering, telephone service, and other departments of PGW; other utilities; contractors, and builders; and bureaus and departments of the city and state.

Special assistant Allen B. Rich maintains a system set up to expedite and control the flow of the necessary orders and instructions through their proper channels. He strives to have the essential information and authorizations for each job assembled and ready for assignment by the time the job is classified "Ready for Installation."

The "Center" also assists supervisors in forecasting the amount of pipe needed in the future. Each month the stores people are informed of the quantity of pipe, by size and material, that the distribution department will need to meet anticipated demands of its work load for the next three months. The stores department bases its inventories on these reported requirements.

On the Street. When assistant supervisor Al Sugumele, right, gets back to the office, he will report the status of this job in North Central section of City to the Work Planning Center. Current status of job will thus be accurately reflected on the planning board. With Al is general gang foreman Forrest Strange. Street workers: Ray Caporale in foreground, Herbert Stokes in rear, George Douglas in trench.

By constantly assembling data about the quantity of construction work, size of jobs, gas required dates, and work order authorization, the "center" presents the supervisors with a composite picture of the known work ahead. This is accomplished by taking the information out of the files and placing it on our visual scheduling panel.

Scheduling Panel

The scheduling panel is composed of four sections: *Personnel,* the *Present Month, Next Month,* and the *Unassigned Work*. It is divided in half. The top section presents Supervisor Stauffer's new business organization and activities. The lower section shows the large main and replacement organization and activities supervised by Supervisor Schlagel.

The "Personnel" section lists the names of the supervisor, his assistants, and gang foremen and inspectors. The number of men in each gang is also shown.

The "Present Month" section lists the jobs assigned to the gangs, showing the estimated gang days required to complete each. The different types of work are indicated by a color code.

The "Next Month" section is the long range forecast panel. Here are tentatively scheduled those jobs the Pre-Inspection Reports indicate will be ready during the next month.

The last division is the "Unassigned" section. On it are listed all the jobs for which there is authorization to install pipe but where the job sites are not yet ready for pipe crews to start working.

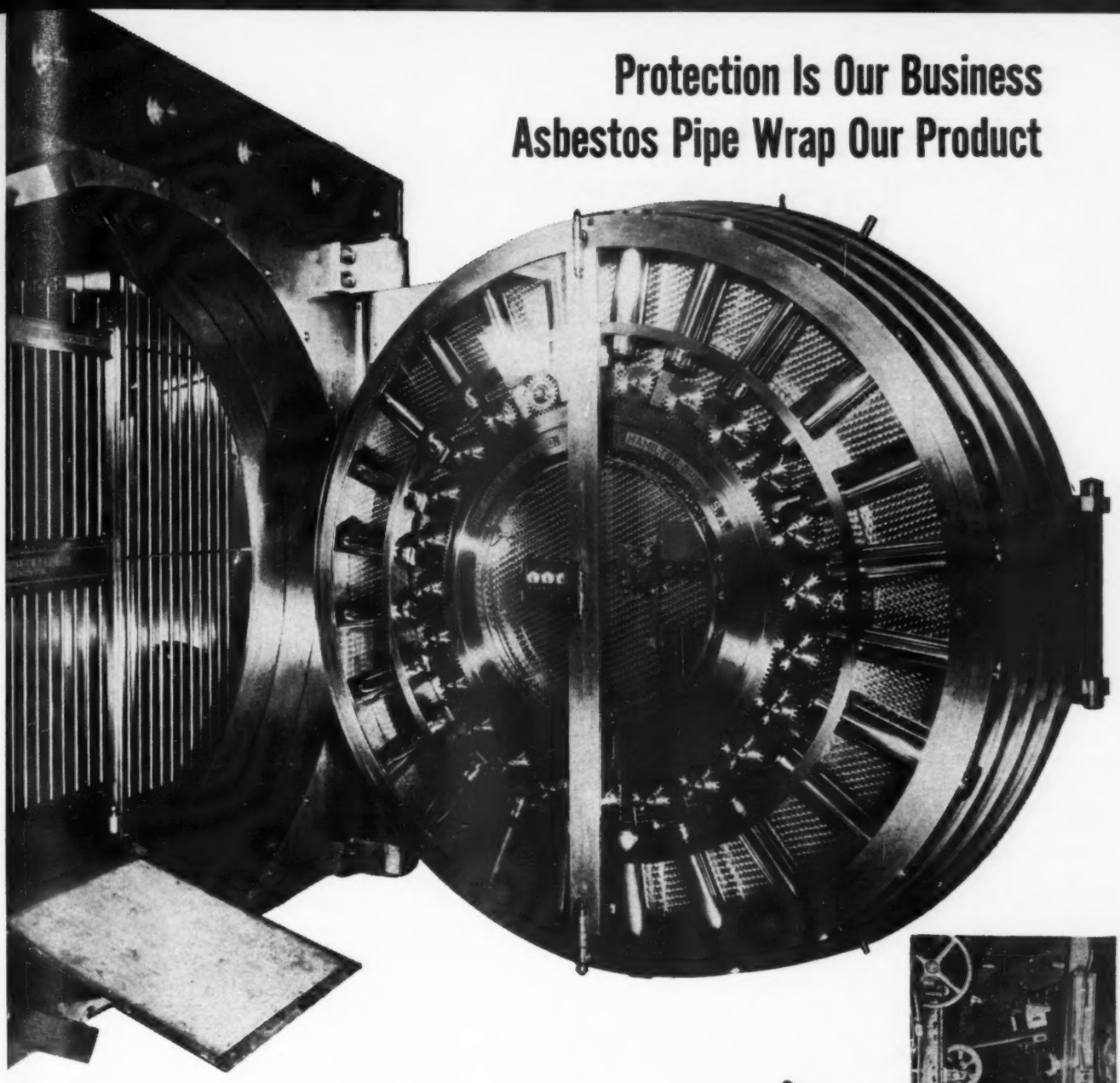
The scheduling system is flexible. Many short-range changes have to be made because of:

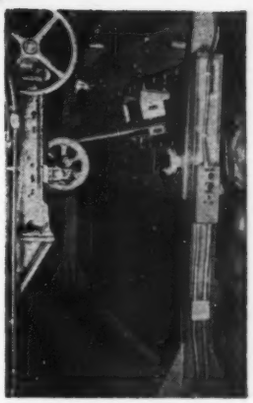
- **Rush work** resulting from situations such as —
  a. No-Heat jobs where small children or sick persons are involved.
  b. Those jobs where ample notice has not been received from the customer.
- **Inclement weather conditions** either slow down or cause work to be postponed temporarily.
- **Priorities** that affect work scheduling and planning such as unexpected installations to be rushed for hospitals and institutions, ahead of paving work, etc.

These are a few of the conditions that interrupt the best laid plans, but must be considered and made to fit into a smooth operating system by rescheduling.

The Work Planning and Scheduling Center is an active part of the Distribution Department. A progressive and dynamic organization must know what lies ahead. The "Center" is constantly scanning the future, composing what it finds into a graphic picture to assist the supervisors to direct their operations more effectively. * * *

Protection Is Our Business
Asbestos Pipe Wrap Our Product





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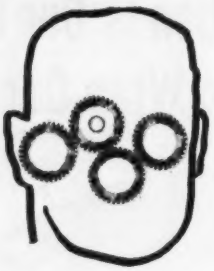
Using the Gears  Between the Ears

LAY THAT SLIDE RULE DOWN!

Part 4

FUN WITH APPROXIMATIONS

Prof. Paul J. Grogan, *Chairman*
Department of Engineering, University Extension Division
University of Wisconsin, Madison, Wisconsin

The Circle Function, π: The ratio of the circumference of a circle to its diameter, π, is clearly defined in mathematics as being a *transcendental number*. By that it is meant the number may not be expressed exactly by any finite arrangement of integer terms. Fortunately, however, it may be approximated by any of several infinite series arrays.

Early history records values of 3, $\sqrt{10}$, and 3⅓ as being used for this ratio. In our earliest encounters with π we were taught to express it simply 22/7. A more recent enlightenment mentions the decimal fraction, 3.1416, as being the logical engineering term. Nevertheless, the latter approximation probably adds unreasonably to the labor involved in a great many simple problems.

The difference between 22/7 and (3.1429) and 3.1416 is observed to be less than 13 parts in 31,400, or less than 1 part in 2,400. To draw an analogy, the indiscretion in using 22/7 rather than 3.1416 is similar to flattering a lady who scales one hundred fifty pounds and one ounce by judging her weight to be a mere one hundred fifty pounds. Therefore, examples offering the opportunity to cancel a seven from the numerator where π is a multiplier might well include 22/7.

For instance, the circumference of a 7-in. outside diameter pipe is obviously 22-in.; well, not exactly, but 21.99 in. The latter dimension might be significant in very precise work, but it would seldom affect the course of ordinary engineering practice.

Further, we should not reach for a slide rule every time 3.1416 is used as a numerical substitution for π. That particular sequence of five digits contains no less than five distinct prime factors: $(2x2x2)x3x7x11x17 = 31{,}416$. They, in turn, lead to an imposing array of over 60 integer divisors with zero remainder. Some of the divisors appear below:

TABLE 4

Partial List of Exact Divisors of 31,416, or 10,000 π

2	3	4	6	7	8	11	12
14	17	21	22	24	28	33	34
42	46	51	56	66	68	77	84
88	102	119	132	136	154	168	187

The product of the last two divisors appearing in the table is expressed, $168 \times 187 = 31{,}416$. Other divisors, 30 in all, may be found by dividing 31,416 by each of the remaining values reported above.

Many of the 60 possible exact divisors of 31,416 are commonly arrayed against π across the line of division in engineering problems. For instance, the brake horsepower equations,

$$BHP = \frac{PLAN}{33{,}000} \text{ and } BHP = \frac{2\,\pi\,NT}{33{,}000}$$

contain many common factors in both the denominator and the numerator. Where the length of stroke is **L** feet, the cylinder bore is **D** inches, the brake mean effective pressure is **P** pounds per square inch, and the power strokes per minute are **N/2,** the former reduces to

$$\text{BHP per cylinder} = \frac{1.19PLD^2N}{100{,}000}$$

where 119 = 31,416 divided by 33 x 4 x 2. The power of 10 in the denominator merely locates the decimal properly.

The right-hand equation above may be reduced to

$$BHP = \frac{19.04NT}{100{,}000}$$

Such devices are convenient in developing brake horsepower relationships for a given engine where additional design variables are known and may be worked into the constants expressed above.

Combining the two equations,

$$BHP = \frac{19.04NT}{100{,}000} = \frac{1.19PLD^2N}{100{,}000}$$

The pound-feet of brake torque per cylinder may be expressed in terms of the brake mean effective pressure and the engine dimensions for any four-stroke, single-acting engine.

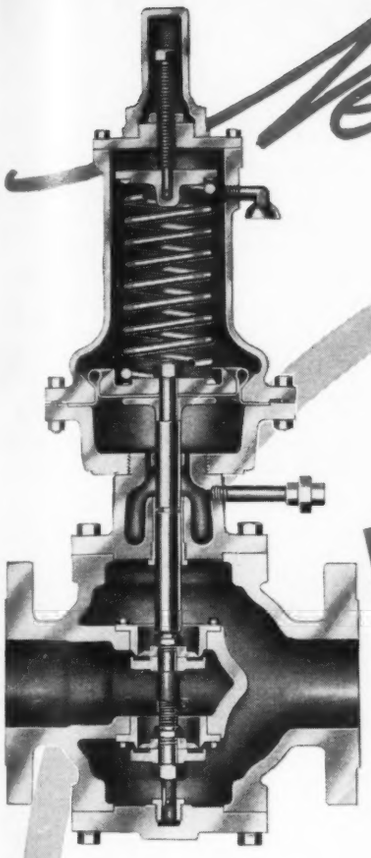
$$T(\text{per cylinder}) = \frac{PLD^2}{16} \text{ pound-feet}$$

The preceding is an exact expression, where 19.04/1.19 is precisely 16. The same result may be obtained by cancelling π from each of the original BHP equations and reducing them to the simplest form. A typical group of student engineers, however, working out a slide rule derivation

New in principle!

CHAPLIN-FULTON

MODEL 441-57S GAS REGULATOR



SIZE: 2"—3"—4"—6"
125 lb. iron—W. P. 175 psi
250 lb. ductile—W. P. 400 psi
Series 30 steel—W. P. 720 psi

Model 57-S, a simple spring loaded regulator, operates on a new diaphragm principle which will control accurately until the regulator is wide open. The outlet pressure "fall-off," typical of spring regulators, is eliminated—not by an uncontrolled velocity effect—but by a diaphragm which changes its size as the valve moves to give straight line control. For pounds-to-pounds service,—controlled pressures to 75 psi with same assembly.

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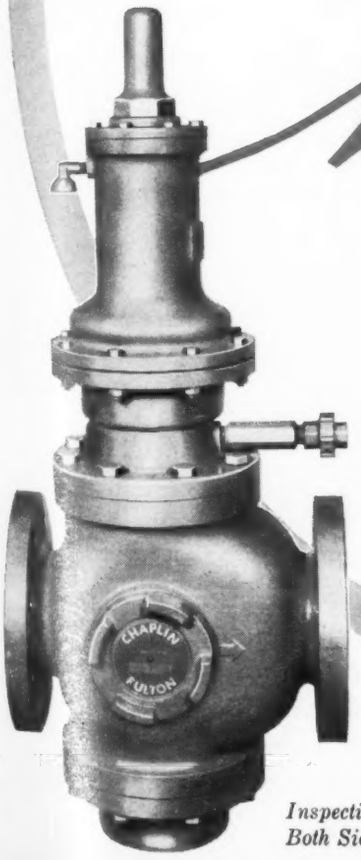

Inspection Plates Both Sides.

Also, a new body design—441—with gas exit areas greatly enlarged to prevent turbulence and increase capacity.
And to help in your visual inspection program—side inspection plates on *both* sides of the body have been included. Screwed-on with O-ring seal, they can be quickly removed and replaced—no gasket problem. Standard face-to-face dimensions now make the 441 interchangeable with other regulators.

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of the constant will introduce a standard deviation of at least three percent in their answers and stand fast in their opinion that it is simply an unavoidable slide rule error.

Cancellation Methods: Approximation methods can be used in another sense, which we shall at first call "rounding off." For example

$$\frac{169}{8.49} \cong \frac{170}{8.5} \cong 20.$$

This method has general use in checking the computational accuracy and the decimal place for any arithmetic exercise. But we need not limit the application of the rule to the mere checking of work as we shall see below.

In the example $\frac{169}{8.49} = \frac{170}{8.5}$, we made an upward adjustment of one part in 170 in the numerator and one part in 850 in the denominator. The numerator, and therefore the answer, is too large by the approximate amount of the difference in these two adjustments. The error becomes 4 parts in 850, or the answer given above is about one-half of one percent too large. Rewriting,

$$\frac{169}{8.49} \cong \left(\frac{170}{8.50}\right)(1 - 0.005) = 20.0\,(1 - 0.005) = 19.9$$

Carried out to five places, the answer is 19.906.

Tackling a more complex problem,

$$\frac{32.16 \times 144 \times \pi}{62.4 \times 778};$$

cancel 32.16 into 62.4 to get 2.00. Keep in mind that the denominator is deficient about 20 parts in 600 or one part in 30. Treat π as 22/7 and cancel 7 into 144, getting 20.0 with an excess in the numerator of 4 parts in 144 or one part in 36. [The use of 22/7 for π is seen above as being of no great consequence, particularly not in mental calculations.]

In many examples the excesses or deficiencies cancel or nearly cancel one another and the solution is clear of further concern about them. In this example, however, the two cancellations to this time have tended to leave an excess in the numerator or a deficiency in the denominator. The combined influence of 1 part in 30 and 1 part in 36 is very closely 2 parts in 33 or 6 parts in 100; that is 6 percent.

There remains to be treated the numbers 22/778. The other two factors involved, being 20 over 2, change this number to 220/778. This represents 2/7 with a one percent excess in the denominator.

The answer, then, is 2/7 plus 6 percent minus 1 percent, or $0.286 + 0.014 = 0.300$. This conforms closely with a slide rule calculation.

Trigonometric Functions: We would like to recall the statement of a fundamental trigonometric proof:

$$\sin \Theta = \Theta = \tan \Theta$$

as Θ approaches zero, providing the angle is expressed in radian measure. Or, interpreting the same information into the more conventional form of angular measurement in degrees:

$$\begin{aligned} 180 \text{ degrees} &= \pi \text{ radians} \\ 1 \text{ degree} &= \frac{3.1416}{180} \text{ radians} \\ 1 \text{ degree} &= 0.01745 \text{ radians} \end{aligned}$$

The decimal value of a one-degree angle, expressed in radian measure, agrees very closely with both the sine and the tangent of one degree as reported in five-place tables of trigonometric functions. Within certain limits, therefore, we may determine either the sine or the tangent of x, where x is a small angle measured in degrees, by finding the product:

$$\sin x \cong 0.01745\,x, \quad \textit{or} \quad \tan x \cong 0.01745\,x$$

The method is hardly more than one percent in error if used for either the sine or the tangent of 10 degrees. It is somewhat closer for approximating the sine function than it is for the tangent. Uniquely, however, it serves closely for either by yielding an intermediate value that represents both the sine and the tangent sufficiently well through the recommended range of 10 degrees. In fact, there is less than five percent error if sin 30° is determined by the same approximation formula:

$$\sin 30^\circ \cong 30(0.01745) \cong 0.5235$$

We know better of course; sin 30° being exactly 0.5. Yet it serves to demonstrate the magnitude of the error in this instance. Furthermore, there is no denying the utility of the method in the expression of:

$\sin 10^\circ \cong 10(0.01745) \cong 0.1745$ *vs* 0.1736, or 0.52% error
$\sin 6^\circ \cong 6(0.01745) \cong 0.1047$ *vs* 0.1045, or 0.19% error
$\sin 30' = \frac{1}{2}(0.01745) = 0.00873$ *vs* 0.00873, or no error
$\sin 30'' = 0.01745/120 = 0.000145$ *vs* 0.000145

Applying the method to the tangent of the angles shown above leads to the same approximate solutions with respective errors of 1.03% and 0.38% in the first two instances. There is no apparent error in the three significant figures of the next two examples whether the sine or the tangent function is expressed.

The approximation method is strongly recommended for determination of the sine and tangent for angles smaller than 6°, where the functions range from 0.0000 through approximately 0.1000. Although the sine and tangent of small angles are generally expressed simultaneously by the ST scale on slide rules, its use remains a hazard if not a mystery to the average slide rule mechanic. Furthermore, there is no provision on the **ST** scale for reading angles smaller than arcsin 0.0100, or smaller than 34.4 minutes of arc.

We may draw upon one of several trigonometric identities to speed us along our path of least resistance in determining further useful trigonometric functions of angles.

It would appear we work most often with cosine components that are but slightly skew with respect to the plane of reference or to the line of motion. We may approximate the cosine by application of the above correspondence between radian measure and the sine function for small angles along with the use of a familiar identity:

$$\cos 2x = 1 - 2\sin^2 x$$
Or, $$\cos x = 1 - 2\sin^2 x/2$$

If the angle x is small, we may substitute the actual radian measure of the angle for its sine function:

$$\cos x \cong 1 - 2(0.01745x/2)^2$$
$$\cos x \cong 1 - 0.0015x^2$$

Applying this simple approximation for finding the cosine of various small angles produces excellent results. The error at 20° is 0.032%, the error at 30° is but 0.115%, and the example below shows that the error at 40° is less than one percent:

$$\begin{aligned} \cos 40^\circ &\cong 1 - 0.00015(40)^2 \\ &\cong 1 - 0.00015(1600) \\ &\cong 1 - 0.2400 \\ &\cong 0.7600. \end{aligned}$$
Whereas $\cos 40^\circ = 0.76604$

The physical interpretation of the method for approximating cosine values is the substitution of the first quadrant

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segment of a parabola for the actual cosine curve. The parabola crosses the Y-axis where $y = 1.000$ and crosses the X-axis where $x = 81.1$. The obvious error is that the curve of $y = \cos x$ does not intercept the X-axis until $x = 90$ in degree measure.

Cosines of angles, say between 0° and 30°, by the foregoing approximation are also practical sine values for the angles between 90° and 60°. A similar statement may be made about the earlier sine function development where cosines of angles between 80° and 90° may be found by evaluating the sine over the recommended ten-degree range.

Strangely, these approximations are about the only practical tool for expressing the functions of extremely small angles such as are encountered in the most exacting of sciences, astronomy. Thus the sine (tangent) and cosine of one second of arc become 0.000004848137 and 0.999999999988, respectively.

The moon and the sun, almost barn-like in appearance in the heavens, subtend but approximately 30 minutes of arc each. Whereas the apparent positions of even the closest stars as viewed from opposite sides of the earth's orbit—at six months' interval—change in the approximate magnitude of one second of arc due to this parallax.

Another useful application of these approximation methods is the elimination of sine and cosine functions from a great many empirical equations where the range of angles are appropriately limited.

Logarithms: Approximations in terms of logarithms are at times useful in obtaining a relative answer where normal computational methods will fail. The difficulty lies in finding a suitable transition piece to change from thinking in terms of real numbers to thinking in terms of the logarithms of those numbers.

It remains very useful to recall that the base 10 logarithm of the integer 2 is very nearly 0.3. The error in this assumption is but one-third of one percent. Now we may proceed to develop a crude, but useful short table of logarithms:

$4 = 2 \times 2$	$\log 4 = 2 \log 2$	$\cong 0.6$
$5 = 10/2$	$\log 5 = 1 - \log 2$	$\cong 0.7$
$8 = 2 \times 2 \times 2$	$\log 8 = 3 \log 2$	$\cong 0.9$
$9^2 \cong 8 \times 10$	$\log 9 \cong \frac{1}{2}(1 + \log 8)$	$\cong 0.95$
$3^2 = 9$	$\log 3 = \frac{1}{2} \log 9$	$\cong 0.48$
$6 = 2 \times 3$	$\log 6 = \log 2 + \log 3$	$\cong 0.78$
$7^2 \cong 5 \times 10$	$\log 7 \cong \frac{1}{2}(1 + \log 5)$	$\cong 0.85$

These approximate values for the logarithms of small numbers make it possible to obtain many other more difficult estimates. For instance, the cube root of two may be found to a remarkable degree of precision through use of these logarithms:

$$\tfrac{1}{3} \log 2 \cong 0.1 \cong \log 5 - \log 4 \cong \log 5/4 \cong \log 1.25$$

The cube root of 2 is closely 1.25.

A second example is to find 2^{10} by these logarithms.

$$10 \log 2 \cong 10(0.3) \cong 3 \cong 3 \log 10$$

Therefore, $2^{10} \cong 10^3$. As a check upon the accuracy,

$$2^{10} = 1024, \quad \text{whereas} \quad 10^3 = 1000$$

The original error of 0.33% has been found to be 2.4% in this application. For this reason, it pays to keep in mind that approximations with logarithms will introduce relatively larger errors than the methods presented heretofore. Nevertheless, these methods will often yield answers that are otherwise difficult to obtain.

Applying the above methods to the perennial poser of the investment that begins with a single penny on the first day of the month and then doubles each succeeding day until the end of the month, we may write the successive investments as $2^0, 2^1, 2^2, 2^3, \ldots, 2^{29}$.

First we should establish that the last day's investment is simply one penny more than the accumulated investment leading up to that day. This may be shown to be true for any day leading up to the last day, and it can be shown to be true for the last day if one persists in the effort. We simply state the second day's investment of two cents is equal to the initial penny plus a penny, the third day's investment of four cents is one penny greater than the three cents on deposit, the fourth day's investment of eight cents is one penny greater than the seven cents on deposit, etc. The total investment, therefore, is very nearly 2×2^{29}, or 2^{30} cents.

Calling upon logarithms to evaluate the unknown number,

$$\log 2^{30} = 30 \log 2 = 30(0.3) = 9.0$$

The number of pennies is 10^9, or one billion. The approximate solution is ten million dollars. The actual solution, excluding taxes, is $10,737,318.23.

For other applications of logarithms in approximation, it is worthwhile to observe that the natural base logarithm of 20 is closely 3.0. Therefore,

$$3 \ln 20 = \ln 20^3 = \ln 8000 \cong 9.0$$

Thus, $e^9 \cong 8000$, and $e^{10} \cong 2.72(8000) = 22{,}000$.

Your slide rule generally limits direct calculations involving exponents to the value, e^{10}, or nearly 22,000.

Now that we are able to express the logarithm of 20 in either of the conventional systems we may use this number then as a means of changing from one system to the other.

$$20 \cong e^3 \cong 10^{1.3}$$

Taking logarithms to an undefined base, produces,

$$\log 20 = 3 \log e = 1.3 \log 10.$$

Selecting e as the base yields,

$$3 = 1.3 \ln 10, \quad \text{or,} \quad \ln 10 = 3/1.3 = 2.3.$$

You may recall 2.3026 as a closer value for the logarithm of 10 to the base e.

Selecting 10 as the base in the example above results in the relationship,

$$3 \log e = 1.3, \quad \text{or} \quad \log e = 1.3/3 = 0.433.$$

The accepted conversion factor is 0.4343.

Moreover, these approximate base 10 logarithms are very useful in constructing semi-log or log-log graphs of any number of cycles, whether on a typewriter or by using rectangular coordinate paper. The following table gives the linear approximation for a number of logarithmic values. The percent accuracy is sufficiently high to fall within the range of accuracy for experimental data or field information as usually obtained. ■

LOGARITHMIC SCALES FROM RECTANGULAR COORDINATES

N	Log N	Rectangular Divisions	Relative Value	Percent Accuracy
1	0.00000	0	0.00000	100.00
1.5	0.17609	7	0.17560	99.7
2	0.30103	12	0.30103	100.00
3	0.47712	19	0.47663	99.9
4	0.60206	24	0.60206	100.00
5	0.69897	28	0.70240	99.5
6	0.77815	31	0.77766	99.95
8	0.90309	36	0.90309	100.00
10	1.00000	40	1.00343	99.7

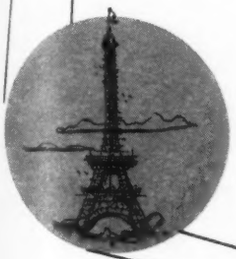
Proved Protection Against Pipe Corrosion Makes PLICOFLEX TAPE the Specified Choice On Major Pipe Line Projects

All Over the Free World

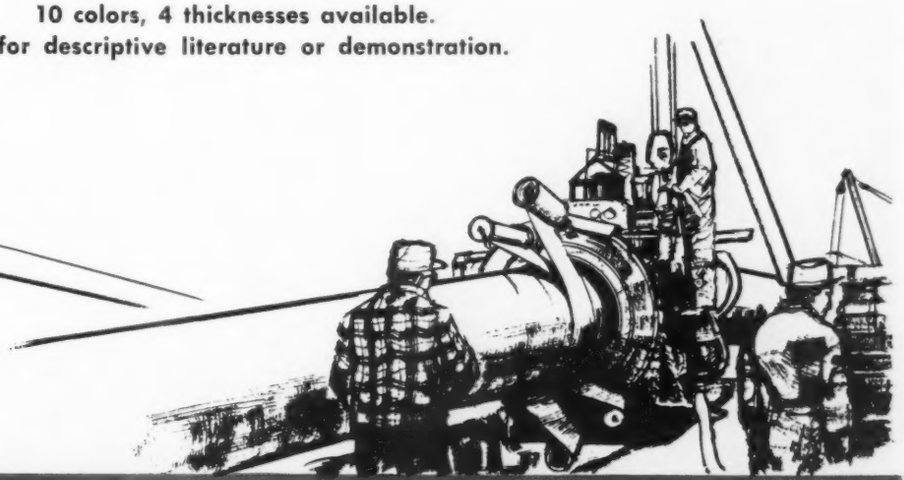
Major pipe line projects in Libya (100 miles of 30″ pipe), United States (80 miles of 30″ pipe), Chile, Tierra Del Fuego oil field (all crude and products lines in field), France (83 miles of 8″ pipe), Colombia (140 miles of 10″ pipe), and the Persian Gulf (6″, 8″ and 12″ pipe), that have used Plicoflex pipe line tape recently (Oct. 1960—Mar. 1961) are only some of the many examples of pipe lines where Plicoflex was the *specified* corrosion resistant material.

Plicoflex laminated butyl-vinyl tape used in combination with Plicoflex butyl base primer is moisture proof · non-conductive · impact resistant · bacteria proof · abrasion resistant · soil stress resistant · chemical resistant.

Application is simple . . . all you need do is give the pipe a good wire brushing, apply the primer at prevailing temperature and wrap and ditch the pipe.



10 colors, 4 thicknesses available.
Write for descriptive literature or demonstration.



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Cast iron pipe rarely needs attention; today 63 American gas utilities still use cast iron gas mains that were installed over a century ago. And modern cast iron pipe, with bottle-tight mechanical joints, offers the same promise of lengthy service. Muscle and dependability—they add up to real savings over the years!

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Thos. F. Wolfe, Managing Director,
3440 Prudential Plaza, Chicago 1, Illinois

CAST IRON PIPE

THE MARK OF THE 100-YEAR PIPE

Distribution Developments

NEWS ABOUT CURRENT AND PLANNED CONSTRUCTION

Montana-Dakota Utilities, Minneapolis, Minnesota, plans to install new distribution systems in six North Dakota communities — Max, Garrison, Turtle Lake, Underwood, Washburn, and Wilton, all in McLean County. Part of a total project estimated to cost $4,288-380, Montana-Dakota has asked for FPC okay to construct a 106 mile 12-in. gas supply line from near Minot to a point on its existing line near Bismarck, a measurement and regulating station near Bismarck, and about 40 miles of branch laterals to serve the 6 new distribution systems and the Air Force Radar Base near Minot, N. Dak. Approximately $455,700 will be spent for the distribution systems proper and $73,600 for gate stations for the six towns and the radar station. Project involves installation of 8000 ft of 2-in. supply line to serve the radar base; 33,000 ft of 2-in. to serve Max; 81,000 ft of 3½-in. to serve Garrison, 29,000 ft of 2-in. to serve Turtle Lake, 37,000 ft of 3½-in. to serve Underwood and 23,000 ft of 2-in. to serve Washburn and 10,000 ft of 2-in. to serve Wilton.

Navgas, Inc., a newly-formed company headquartered in Charleston, West Virginia, plans to install a distribution system at the U. S. Naval Radio Research Station at Sugar Grove, Pendleton County, W. Va., and has asked the FPC to direct Atlantic Seaboard Corp. to connect and supply the new system at a point 18 miles southwest of Moorefield, W. Va. Total cost of the proposed project is $632,100 with $492,878 tabbed for a 24.2 mile 6-in. supply lateral to be built by Navgas, $49,741 for installation of the distribution system, and $14,927 for the gate station. Approximately $196,987 is included to purchase pipe for the supply lateral, $26,443 for 17,000 ft of 1 to 4-in. mains and $4299 for services, $1423 for house regulators and $1858 for house regulator installations. Navgas wants to start construction by July 1 and finish November 1. R. A. Ransom Co., Inc. of Washington, D. C. is consulting engineer on the project.

Southern Union Gas Company, Dallas, Texas, has set a $10,239,477 total construction budget for 1961. New office building to be constructed in Albuquerque calls for approximately $500,000 of the total $2,500,000 set for expansion in that district. In Arizona, $750,000 is budgeted for expansion of mains and services; in Austin, construction will total $1,130,000, about $145,000 more than spent last year for expansion and improvement of facilities. In Carlsbad district approximately $500,000 is expected to be spent; in Clovis a total of $122,000 is budgeted; in El Paso, $1,018,000 is budgeted for construction in El Paso itself, and $72,000 for the Alamogordo area. Improvement and extension of equipment in Galveston district is estimated to cost $80,000 for 1961. In Port Arthur, $413,000 will be spent on expansion this year; in the Santa Fe district, expansion of distribution facilities will call for $550,000 of which $290,000 will be spent in Santa Fe and $105,000 in Farmington area. West Texas district rounds out total budget with $122,000 allocated for construction.

Alabama Gas Corporation, Birmingham, Alabama, has construction underway on installation of 24,400 ft of 12-in. feeder main in Birmingham, Jefferson County, area. Estimated cost of the project is $270,000. Work is scheduled to be completed September 15. Also underway is installation of a small distribution system in the Montgomery district, Elmore County. Estimated cost of the project is $123,000; includes installation of 83,272 ft of 4, 3, 2, 1½, and ¾-in. intermediate pressure mains and services. Work is scheduled to be completed by last of August.

Fitchburg Gas and Electric Light Company, Fitchburg, Massachusetts, plans to extend its gas distribution lines in the Pearl Hill, Fisher, and Ashby State roads section of Fitchburg. An additional extension is planned from White Street and Maple Parkway to Massachusetts Avenue in Lunenburg.

Union Gas Company of Canada, Ltd., Chatham, Ontario, has acquired complete ownership of Kingsville, Ontario's natural gas distribution system at an estimated cost of $25,000. Company formerly owned two-thirds of the system.

In another project, company crews recently completed replacement of 13 miles of 6-in. line including an 8-mile stretch on the Tillsonburg-Caledonia line near Jarvis.

Dayton Power and Light Company, Dayton, Ohio, plans to spend $52,196 to install a distribution system in the unincorporated community of Russia, Laramie Township, Shelby County, Ohio. Project includes installation of a 3841 ft 3-in. supply line from Ohio Fuel Gas Co. transmission facilities, 1495 ft of 4-in., 6630 ft of 3-in. and 3758 ft of 2-in. distribution mains and services. Included in the total cost is $13,763 for pipe and station regulator; $31,901 for installation and overhead; $3087 for domestic regulators and meters, and $3445 for gas services.

Town of White Bluff, Tennessee, a new municipal gas distribution company, has asked FPC to direct Tennessee Natural Gas Transmission Co. to establish connection facilities with those to be constructed by the municipal and sell and deliver gas to the new system. Estimated total cost is $120,000 of which $85,100 is for pipe, valves, service assemblies, and other materials; $6600 is for engineering, $1800 for legal and administration fees; $900 for right-of-way; $14,000 for interest, $3000 for working capital and $8600 for contingencies. Of the direct tangible costs approximately $12,600 goes for 12,600 ft of 2-in. supply line, $42,919 for 37,320 ft of 2-in. distribution lines, $6048 for 9190 ft of ¾ to 1½-in. service lines, $2000 for a town border station and $4730 for a regulator and odorizer.

First Utility District of Maury County, Tennessee, plans to construct a new distribution system in Mount Pleasant, Tenn., and has asked the FPC to direct East Tennessee Natural Gas to connect and serve. Total cost of the proposed distribution system is estimated at $350,000 with approximately $216,000 allocated for direct costs. Project consists of installation of 118,600 ft ¾ to 4-in. steel mill-wrapped and coated mains at an estimated cost of $140,614, one regulator ($10,000) and 300 service assemblies ($13,500). Harbert Construction Corp. is contractor.

Interstate Power Company, Dubuque, Iowa, plans to install a $94,800 distribution system in Albany, Ill. and has asked FPC to direct Natural Gas Pipe Line Co. of America and Natural Gas Storage Co. of Illinois to connect and serve the new system. Project consists of installation of 5000 ft of 4½-in. supply lateral at a cost of $15,300; 6000 ft of 4½-in. and 21,000 ft of 2-in. distribution mains at a cost of $63,200. Installation of undetermined amount of services will account for another $14,500.

BUCKEYE 308 RUNS WIDE OPEN THROUGH ROCKY N. DAKOTA HILLS

Ditcher Takes 45° Grades Without Tow Tractor

A Gar Wood-Buckeye 308 is cutting 6,000 feet of ditch per day through rock and hard clay in the foothills of northwestern North Dakota.

The job is a 55-mile, 10-inch pipeline being laid between Minot and Newburg. Contractor is Curran Construction Ltd. of Edmonton, Alberta, Canada.

Curran reports the 308 has been running wide open, and has ditched as much as 9,500 feet in a day. Even grades as steep as 45° haven't slowed down the sure-footed 308—a tow tractor has never been needed.

Curran's ditcher operator, Bill Rose, calls the Gar Wood-Buckeye 308 the finest all-around ditcher he has ever operated. Singled out for special praise by Rose: the 308's outstanding hydraulic conveyor drive.

This drive, with its three speeds in either direction, allows instantaneous, on-the-go adjustments of the spoil pile—without complicated shifting, without stopping crawlers or digging wheel. And the entire operation of the conveyor is controlled by simple levers located at the operator's fingertips.

Contractors across the country are getting more ditch for their dollars with Gar Wood-Buckeye ditchers. Your Gar Wood-Buckeye dealer can show you why.

GAR WOOD ENGINEERING MAKES BUCKEYES RUGGED ENOUGH TO RIP THROUGH ROCK

To meet fast production schedules through terrain as tough as North Dakota's, the Gar Wood-Buckeye 305, 307 and 308 ditchers are more than just "ruggedly built." They are scientifically engineered to resist stress, to cut vibration to a minimum, and to deliver the greatest useful power to the digging wheel.

An all-welded panel truss frame supports the digging wheel and conveyor assembly of these machines—is exceptionally rigid and resistant to stress. The wheel itself is formed of two steel rings welded together for far greater strength. And the unique Buckeye digging buckets are of two-piece construction for greater abrasion resistance and easier maintenance.

Exclusive features like these—the result of 68 years of ditcher engineering—make Gar Wood-Buckeye the *outstanding* choice in ditchers, no matter how tough the terrain.

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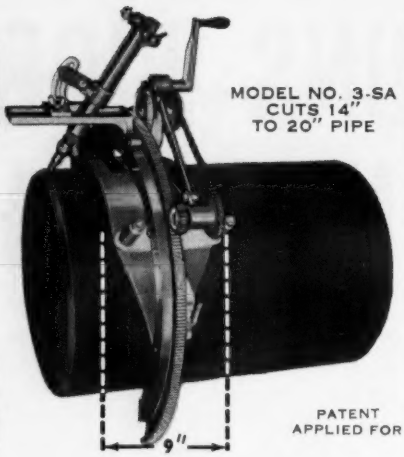

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- More rugged . . . this new design produces a more stable ring gear assembly, which is less likely to spring or warp.
- Retains extreme accuracy of cuts, which all Mathey Pipe Beveling Machines are noted for.
- Available in all sizes, from No. 1 to No. 5 machines.

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Distribution Developments

Mississippi Valley Gas Company, Jackson, Mississippi, plans to add a new customer — the Naval Auxiliary Air Station in Lauderdale County near Meridian, Mississippi, and has asked the FPC to direct Southern Natural Gas Co. to connect its transmission facilities with those Mississippi Valley plans to install. Total estimated cost of $105,530 is to be borne by the Air Station. Planned is a 37,200 ft 4½-in. line estimated to cost $96,830 and including $42,200 for materials. Line will run from the south boundary line of the Naval Air Station near Meridian to a point of proposed inter-connection with Southern's 6-in. transmission line. Intake pressure on the line is to be 175 psi, outlet pressure, 50 psi; maximum volume of gas carried will be 106,000 cu ft per hour. Another $8700 will be spent for a measuring and regulation station. Included in this cost are: $3600 for meter and regulator; $3000 for other materials; $1200, labor; $100 for engineering and inspection, and $800 for survey, administration overhead, interest, and contingencies. FPC gave project temporary approval March 23.

Citizens Gas Company, Tuscola, Illinois, plans to build a new gas distribution system in the village of Hume, Illinois, pending authorization for a gas supply allocation from Panhandle Eastern Transmission Co. *(Application was filed with FPC January 16.)* Proposed is a $63,242 gas distribution system consisting of 10,000 ft of 2-in., and 14,000 ft of 3-in. mains operating at intermediate pressure ranging from 10 to 60 psi. Approximately $12,300 has been allocated for pipe; $3900 for coating and wrapping at the mill. Approximately 20 valves and fittings, costing $1500, and 75 meters, costing an estimated $2775, will be installed. Cost of installation of mains, valves, curb services, meters, and town border station is estimated at $24,375.

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How you can get the *MOST DIGGER* for your equipment dollars

DIGGING • LIFTING
HANDLE WITH CASE *Utility*
LOADING • CARRYING

When you're shopping for a backhoe rig, you naturally weigh the work capacity of each machine in terms of the dollar-outlay involved and possible lowered costs for operation and maintenance. Here are some facts that will help you get the most for your company's equipment dollars in 3 typical situations:

I. If you are in the market for a high-speed rubber-tired hoe, you can get a *14′ digger at a 12′ price* by investing in a Case 530 *Utility* Backhoe-Loader. Powerful backhoe gives you 13,000-lb breakaway at full reach from pivot. It reduces dig-dump cycle-time with *exclusive* foot-controlled hydraulic swing. Model 530 is built for heavy day-in and day-out digging with alloy-steel boom, dipper stick and buckets; powerful hydraulics . . . plus equally rugged 2000-lb front loader.

II. If you need a mobile digger for trenching to *only 10′ deep,* you'll get a *heavy-duty machine at economy-rig cost,* in a Case 430 *Utility* Backhoe-Loader. This 10′ machine gives you 10,000-lb breakaway at full extension of boom . . . rugged tractor and 1200-lb loader, all similar in design to the big Case 530 rig.

III. If you're looking for a low-cost *crawler* hoe for work in mud, snow, or rough going, you'll *save $1000's on the purchase of such a rig,* with a Case 310 *Utility* Crawler Backhoe-Loader. This unit incorporates the same rugged, fast-digging 14′ hoe as Model 530 (above), but on a powerful compact Model 310 crawler tractor with husky ¾-yd front loader. You don't have to buy a big tractor or shovel-type hoe for 14′ deep trenching.

See Case *Utility* FIRST . . . for the biggest dollar-value in backhoe-loader units. Call your Case Dealer for free demonstration of any or all 3 models. Or for free descriptive literature, write J. I. Case Co., Racine, Wis., Dept E1731.

CU-BL-300

Model 530. This rig is equipped with power-steer, shuttle transmission and special tires for extra dig-power and speed with 2000-lb loader.

Model 310. Here is the easiest-operating crawler tractor on the market. You can hop right in from a rubber-mounted rig and feel "at home".

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Distribution Developments

Western Gas Fuel Company, Hastings, Nebraska, (wholly-owned subsidiary of Kansas-Nebraska Gas Co.) has completed construction of 6 intermediate and low pressure distribution systems in Nebraska. Work involved installation of 31,500 ft of 1 to 8-in. mains and stubs in Chadron; 48,400 ft of 1 to 6-in. in Crawford, 73,300 ft of 1 to 6-in. in Gordon; 31,200 ft of 1 to 4-in. in Hemingford; 38,000 ft of 1 to 4-in. in Rushville; and 29,100 ft of 1 to 4-in. in Hay Springs, Nebraska. Work in Crawford, Gordon, Hemingford, Rushville and Hay Springs was contracted to Brodie Construction Co. of Amarillo, Texas.

Niagara Mohawk Power Corporation, Syracuse, New York, has two major projects scheduled for 1961. An electronic data processing system, installed late in 1960, will be used first to handle calculating and processing of a million customer bills per month. It will later be used in planning, engineering, operating, and other aspects of company's business. Also in 1961, a centralized electric and gas meter shop near Syracuse, equipped to test and service nearly 200,000 meters per year, will be completed. This central facility will enable Niagara Mohawk to service its entire 22,000 sq miles of service territory and eliminate necessity of local meter repair facilities.

Iowa Southern Utilities Company, Centerville, Iowa, plans a $69,355 gas distribution system in Danville, Iowa. Project will include installation of 3400 ft of 4-in., 16,900 ft of 2-in. coated and wrapped mains. Approximately $7434 has been labeled for meters and regulators and $12,637 for installation of customers' services.

Public Service Electric and Gas Company, Newark, New Jersey, plans to install during 1961 approximately 300 miles of mains, 24,600 services, and 27,700 meters. The 300 miles of mains will include 8 miles of high pressure steel main to supply additional natural gas to the city of Paterson and reinforce supply of natural gas to rapidly expanding Oakland-Franklin Lakes-Wayne area. Company also plans to convert approximately 120,000 gas customers, principally in the Paterson area, from mixed gas operation to the use of straight natural gas during 1961 as natural gas is introduced in new areas.

Oxford Natural Gas Company, a new company headquartered at 1418 Melrose Building, Houston, Texas, plans to build a distribution system to serve the city of Oxford, Ohio, (pop. 7,828) and has asked the FPC to direct Texas Eastern Gas Transmission Co. to establish connection with facilities it proposes to construct. Total cost of the project is estimated at $587,500 and includes $191,500 for a 12-mile lateral supply line (48,500 ft of 6-in., and 17,100 ft of 12-in.) and regulator station; $181,160 for installation of 22,400 ft of 4-in., and 59,150 ft of 2-in. mains; and $132,980 for 62,025 ft of ¾ thru 2-in. services. Oxford anticipates installation of 791 customers, 7 industrial meters, and 90 farm taps. Total cost also includes $17,860 for engineering, survey, and inspection.

Ohio Fuel Gas Company, Columbus, Ohio, has construction underway on an $86,700 project to improve natural gas service in Avon, Avon Lake, Bay Village, and Westlake. New town border station will be constructed at intersection of State Route 20 and Lear-Nagle Road. In addition, about a quarter of a mile of new 10-in. line will be laid to tie new station into O-F's system. Burkhardt Construction Co. is contractor. Project is expected to be completed about middle of April.

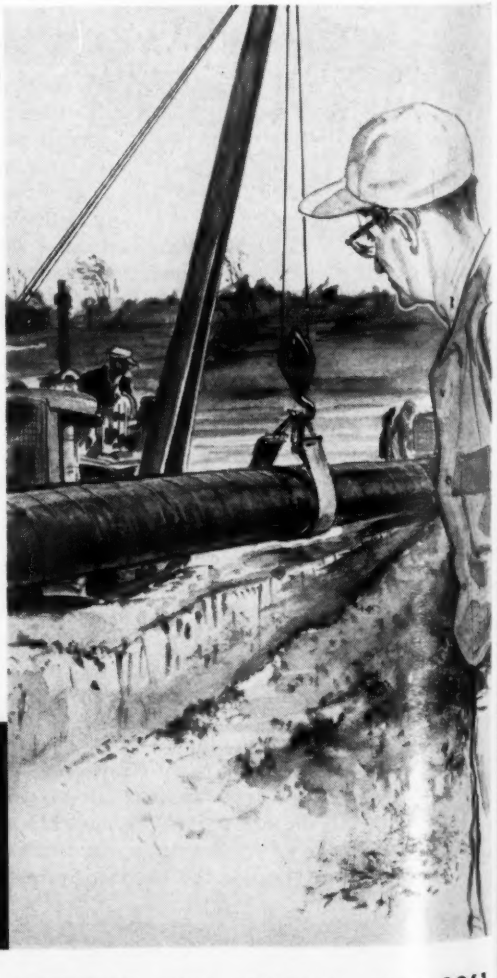
KERMAC Outerwrap KERMAC

resists damage during lowering-in and backfilling

Kermac — the tough, durable glass Outerwrap — provides thoroughly reliable protection against the damaging effects of soil stress. Reducing the threat of costly holidays that often result from these operations is important to the economy of any pipe line, and Kermac Outerwrap is designed specifically for that purpose.

Kermac's bonded, fibrous glass mat is reinforced by strong glass yarns, and is saturated with special bitumens. These outstanding features assure a constant and adequate safeguard for your protective enamels during lowering-in and backfilling.

Your Midwestern Man is a ready and reliable source for further information or assistance on this important material. Call, write or wire.



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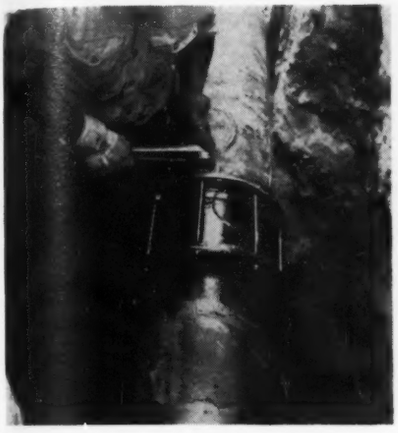

Permanently coated coupling . . . said to eliminate field coating of couplings in the ditch, . . . has been developed by Dresser Manufacturing Co. Coating on the coupling has unusual feature of being concealed by useful but expendable outer shell, while independently assuring 99.2% protection against corrosion-causing holidays. Electrical continuity of the "Stab Clad" Style 123, coupling is achieved thru special bonding device that assures cathodic protection against corrosion. Installation is said to be as easy as "one, two, three."

Couplings are coated with coal-tar, epoxy resin composition applied after the Red-D Shopcoat, then subsequently immersed in a hot coal-tar enamel following a carefully controlled factory sequence of timing and heating. Heat from molten bitumen causes a simultaneous curing of both phenolic resin coating and the epoxy resin, bonding the three coats together. This results in a non-disbonding layer of 5 to 25 mils of heat-cured permanent coating, shielded by outer layer of coal tar enamel. 8-page bulletin describes new coupling completely. **1**

Plastic pipe jacket shrinks to size, provides corrosion-resistant protection to pipe, fittings, couplings. An overseas import, new polyvinyl chloride tubing is resistant to soil acids and bacteria, is available in variety of diameters and wall thicknesses, and has contraction factor 50% its original diameter. Dipping in hot water or exposing to hot air shrinks new tubing to contours of pipe. **2**

Rotary Meters . . . Full information is available on American Meter Co.'s new line of American Rotary Meters recently announced as available through an agreement with Roots-Connersville Blower Division, Dresser Industries, Inc. The complete line of positive displacement rotary meters will be available to gas utility companies and others thru American's regular channels in U. S. and Canada. Both rotary meters supplied by Roots-Connersville to American and the meters Roots-Connersville will continue to sell as Rootsmeters through their sales organization will be available with base pressure and base volume indexes and accessories made by American. American rotary meters are available in capacities to 1,000,000 cfh and in working pressures of 125,600 and 1200 psi. **3**

Pulse rate detector . . . designed and developed by Guardian Electric Mfg. Co. . . . can serve as supervising control where time rate function of pulsing contacts or special signal pulsing systems require alarm when contacts fail, or pulse rate in a supervised pulsing system varies from set parameters. Of a compact, solid state, module plug-in construction, detectors are either fixed or adjustable types capable of delivering up to 15 watts for actuation of alarm relay or other type control device. Detectors are available for use on any desired line supply. **4**

Vaporizer for small commercial, industrial, and agricultural LPG-Gas users is now available from American Liquid Gas Corp. Model 40/40, a direct-fired vaporizer, has a rated capacity of 40 gal per hr, and is said to incorporate efficient operation with low installation costs. Has baked enamel finish on the inside and outside of the case. Complements larger size vaporizers, vaporizer-mixers and carburetion equipment manufactured by ALGAS. Complete information on unit, installation, and service available upon request. **5**

Automatic chart changer . . . a simple attachment that makes a recording instrument fully automatic in operation, permitting it to run for days or weeks completely unattended . . . is described in new, 4-page illustrated bulletin from Mullins Mfg. Co. Any recording cycle is said to be possible and any standard make, model, or type of recorder, can be converted. Any standard circular chart can be used, the only modification being a single, keyhole-shaped slot in center of chart. As many as 50 charts can be group loaded at a time. Completed charts are stored in chronological order in metal chart catcher mounted below the recording instrument. **6**

Looking to the Future . . .

Projections show that by 1970 the population will be increased by 33 million. One way the natural gas industry is preparing for this greater market of gas sales is by increasing money assigned for research. So are manufacturers, and some of the resulting new products now available are briefed here. You can get additional information by circling . . . *on the reader reply card in this issue* . . . the numbers at the end of each item.

Plugging Pig . . . for plugging and evacuating lines for replacement or repair, hydrostatic testing of existing lines, and hydrostatic testing of new lines . . . is described in new 8-page bulletin. New pig has device for simple, positive alignment and locking in place. By using the plugging pig operator can minimize down time or eliminate it if by-pass is extended beyond first plugging pig. There is virtually no loss of line contents. Other advantages are: eliminates need to vent line, no heavy equipment needed on job site, no large fittings left on line, and line is purged with inert substance before cut is made. Positive seal of the pig is assured during duration of job. **7**

Industrial gas equipment . . . for heat process engineering . . . is described in new 16-page fully illustrated brochure just released by Gas Appliance Service, Inc. Among units described are the gas/air-mixer units for accurately premixing gas/air mixtures of any commercial gas — manufactured, natural, mixed, propane or butane — and their applications in automatic brazing and soldering where accurate heat control is required, flame hardening where highly concentrated heat input is required, in furnaces requiring high rate of heat input and atmosphere units for furnishing accurately controlled inert gas. The ZigZag burner, for fast localized heating, is also shown together with burner capacities chart. Brochure also covers heating units for flame heat treating, silver soldering, soft soldering, brazing, and annealing. **8**

The MINIATURIZED-PRECISION WILKINSON Line Locator Model W-3

This radically new, super-powered, transistorized instrument weighs only four pounds and is one-fourth the size of conventional pipe locators.

It is as handy as a flashlight; the maintenance is trivial; the non-leak miniature batteries last ten times longer. Long-life transistors eliminate replacement. Molded glass fibre cases. Transistor ear set. Telescopic handle. Etched circuitry. Contained in carrying case.

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OUT-BEVELS A BEAVER

Throughout history, Nature's most effective beveling machine was a furry little animal called the beaver. Unfortunately for him, through the years jobs came up that were beyond his power (beavers have proved highly ineffective on steel pipe). Today, the beaver has been retired to the forest because H & M now covers the beveling market. There are seven standard H & M models, designed to cut and bevel any size pipe from 1½ inches through 36 inches. H & M's Out-of-Round attachment, which fits all H & M machines, makes it possible to cut irregular shaped pipe accurately and has eliminated costly, inaccurate cuts. The H & M Shape Cutter fabricates tees, els, saddles and other irregular shapes quickly and accurately. The H & M "BEVEL-LAND" Grinder smooths and cleans pipe cuts and bevels in a matter of seconds. Retire **your** beaver to the forest — not only does the H & M line do the finest job possible, but it doesn't have to be fed (another saving passed on to you).

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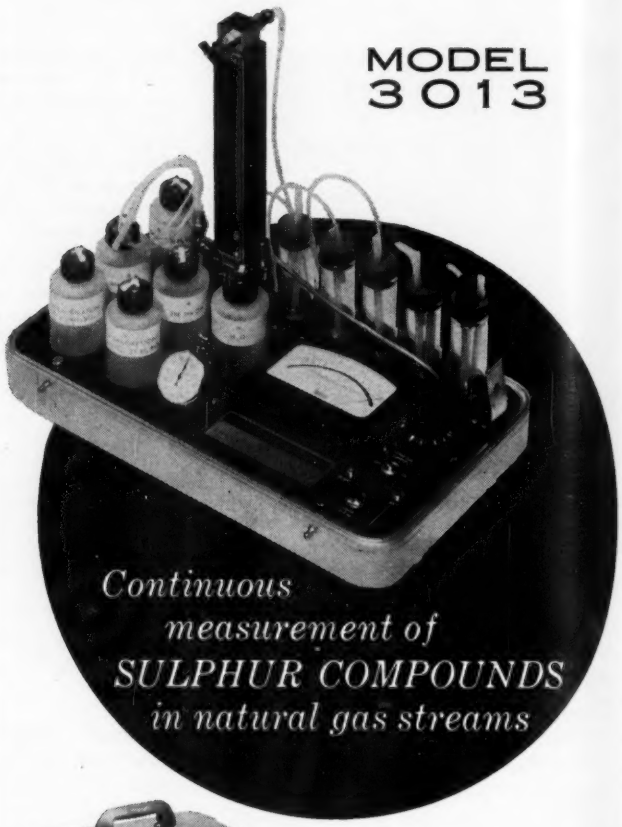
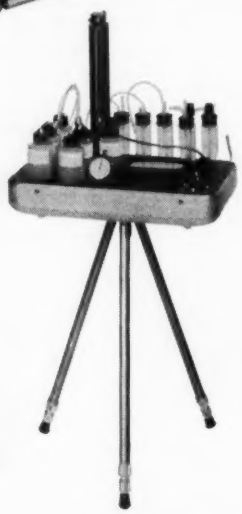
AUSTIN GAS TITRATOR

MODEL 3013



Continuous measurement of SULPHUR COMPOUNDS in natural gas streams



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PRODUCT PARADE

Pipe Coatings . . . available from Protecto Wrap Co. . . . are described in two new bulletins. The CA 160 Mastic pipe wrap is thick heavy bodied, solvent release, cold-applied coating formulated specifically for protective coating of steel pipe, tanks, and similar buried equipment. Protecto's No. 200 tape is a coal tar enamel-synthetic resin coating in tape form. A film of polyvinyl chloride is bonded to the outside surface of the tar. Addition of this group of synthetic resins to the enamel is said to have upgraded quality of the tar by increasing its density and ductility and by increasing its water and oil repellent characteristics. General information, primers needed, and applications techniques for both wraps are described in the bulletins. **9**

Packaged burners . . . for large commercial and industrial applications . . . are described in new bulletin from Webster Engineering. Of the Series R center diffusion gun type, these gas or gas/oil burners are available in factory-packaged forced-draft units of the general type. Four basic registers — 19, 23, 26, and 30-in. — are combined with proper blowers and accessories to provide range of inputs from 4 to 70 million Btu/hr. **10**

New pilot-loaded regulator package from Rockwell Mfg. Co. . . . originally designed to meet constant gas flow requirements for seasonal heating of tobacco curing barns . . . can be used wherever accurate control of outlet pressure must be maintained over full capacity ranges. Combining a cast iron 173 high pressure regulator assembly and standard diaphragm with an 080R pilot, the new unit has operating range of 10 to 100 psi gage inlet pressure, 2 to 20 psi gage outlet pressure. Its capacity ranges from 2000 to 15,000 cfh of 0.6 gas, dependent upon pressure and orifice size combination. Available in 1-in. by 1-in. standard and ¾-in. by ¾-in. optional connection sizes. Standard orifice size is ¼ in. **11**

Brother Juniper

"I'd appreciate it if you'd wipe your big cubic feet before walking on my nice clean cellar floor!"

In a special appeal to the economy market, Dearborn Stove Co. has introduced a Baronet series of vented gas area heaters that are said to "combine new and traditional Dearborn quality features." Heaters are available in 12 models — a B series and a C series, each of which has 6 models in a range of 35, 50, and 65 thousand Btu's. The series vary according to standard and optional equipment and use of natural and LP Gas. New heaters excel in heating ability, basically because their combustion chambers are composed of multiple heat exchangers affording high degree of circulation and warm air volume. Combustion chambers are seam-welded single units made of heavy gage steel. **12**

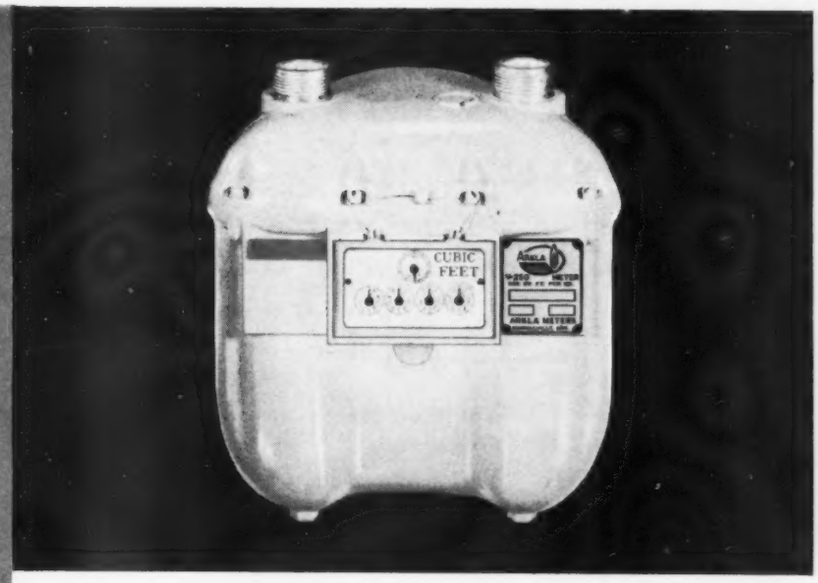
Drafting room equipment catalog . . . a new 32-page product and planning guide published by Hamilton Manufacturing Co. . . . describes equipment advances in the engineering field designed to reduce fatigue, increase individual draftsman efficiency, and dramatically save floor space. If you have a problem filing engineering materials, whether they be flat, rolled, active, semi-active or inactive, this catalog may help you. **13**

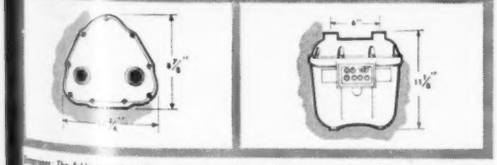
New bulletin from American Meter Co. describes Reliance Type Y and Y-DC low pressure regulators recommended for domestic appliance service applications such as on water heaters and space heaters, house heating furnaces and similar installations where constant gas pressure is essential. Maximum inlet pressure is 1 psi with outlet pressure to 10 in. wc. Type Y is available in sizes from ⅜ to 1¼ in. and Type Y-DC in sizes from ¼ to ½-in. **14**

THE ARKLA

V 250

GAS METER





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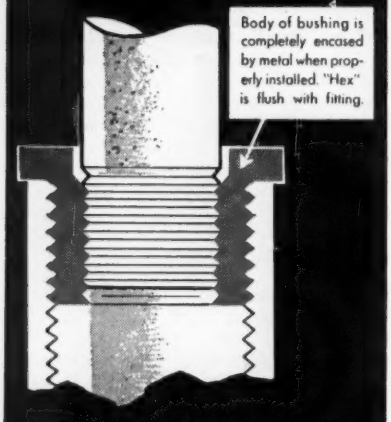

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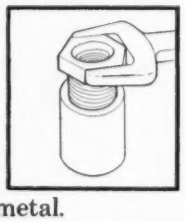

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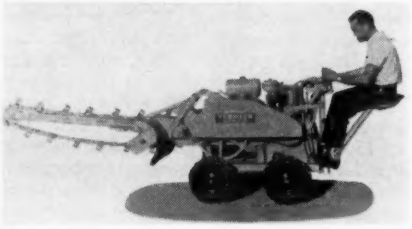
PRODUCT PARADE



Newest addition to Vermeer's line of Pow-R-Ditchers . . . and the smallest . . . digs up to 8 in. wide and is designed to be used by contractors and utilities for laying small service lines. Unit features all-hydraulic ground travel, regardless of digging speeds or transport speeds. Has 4-wheel drive on 4.00 x 8 tires or can be equipped with crawler tracks. Is powered by 9-hp engine. Special ejector paddles deposit dirt neatly on both sides of ditch rather than thrown over wide area. This enables faster, easier backfilling and cleaning of area. **15**

Meter swivels and meter nuts . . . for accurate alignment of gas meter sets . . . are described in new 2-page bulletin issued by Gas Service Products Div. of Eclipse Fuel Engineering Co. Construction advantages are described. Offset, adapter, and straight meter swivels and meter nuts are pictured; three typical installations using these gas service products are illustrated. **16**

Improved insulated couplings and fittings from Norton McMurray Mfg. Co. incorporate a semi-insulating gasket and nylon insert combination, or a full rubber insulating gasket to give maximum insulation. The nylon is said to have very high dielectric strength, while the insulating gaskets themselves have low carbon content. Detailed data on units and their adaptations available on request. **17**

A larger model . . . 7000 cfh . . . has been added to Roots-Connersville Blower's line of rotary positive displacement meters. This line-mounted meter has all field-proved features of 3000 cfh meter: is compact, easily installed, permanently accurate, and requires minimum maintenance. Is recommended for distribution, industrial, and commercial gas measurement at pressures to 125 psi. Connections are flanged to ASA C.I. standards for easy mounting in 3-in. pipe. No special supports required. Literature details specifications. **18**

Starting-Motor power system . . . especially useful where gas engines are used as prime movers . . . is detailed in literature available from Alectric Mfg. Co. The system, sometimes referred to as "transtarter control system," eliminates need for automotive type battery, operates from a-c power lines, requires 220 or 440 v single phase 60 cycle line. A dual voltage unit provides 6 or 12 v d-c with intermittent duty same as automotive starter. A 24-v d-c single voltage system is also available. Among system's advantages are elimination of wet batteries, maintenance confined to 2 relay contacts, elimination of toxic fumes, battery odors, and corrosive elements. Unit becomes more efficient with reduced temperatures, is ideal for cold-room service. **19**

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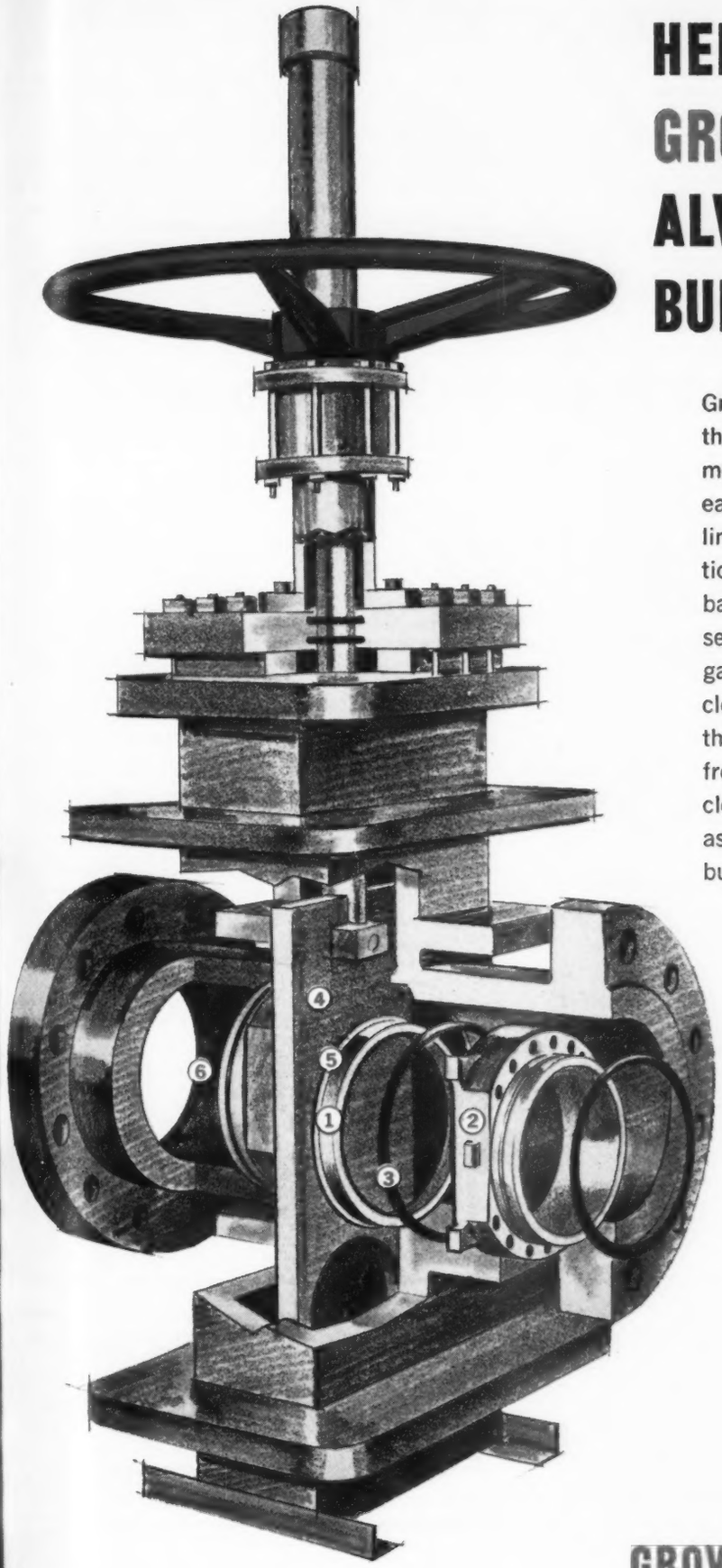

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Grove protected Seal-"O"-Ring® system is the heart of the G-4. Inner (1) and outer (2) metal seat rings shield the o-rings (3) on each side of the gate (4) from damage by line contaminates. Inner seat rings also function as a primary metal-to-metal seal (5) backed up by the o-rings. No lubricants or sealing compounds are needed. The floating gate and seats assure fast, easy opening and closing, and positive, bubble-tight sealing; the inner metal rings scrape foreign matter from the gate while the o-rings squeegee it clean. Through conduit (6) is provided to assure ideal flow characteristics. Send for bulletin #571.

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PRODUCT PARADE

Ductile iron pipe from McWane Cast Iron Pipe Co. is described in new 16-page brochure. Details of manufacturing such as melting, pouring, and quality control, are given as well as specifications of mechanical joint pipe and ductile iron pressure pipe. Ductile iron is said to retain age-old corrosion resistance of gray cast iron pipe, yet has capacity to withstand high pressure, absorb shock and stress in handling and laying. High ductility and toughness allows pipe to be bent without breaking. Available in 2 to 12-in. diam. **20**

For silence. Burgess Manning's redeveloped and engineered series of engine exhaust snubbers for reduction of noises of engines, blowers, compressors and vents is described in specification bulletins. New series is result of intensive 2-year development program and will be marketed as the BMA-First Line, BMB-Standard, and BMC-Compact. Available from 8-in. thru 30-in. **21**

Bendix brochure describes the G-20 high-speed computing system, detailing its outstanding operational features and including the recently announced improvement in G-20 computing, magnetic tape, and line printer speeds. Booklet also describes increased memory and processing facilities of system's control buffers and the system's unique communication system. Basic, medium, and large systems are depicted. **22**

New nylon clamp . . . for use with plastic or metal pipe . . . is said to withstand vibration, pinching of pipe or bending at any point. Has molded wedge that prevents entrapment or pinching in harness bundles and provides true round diameter for retaining tubing thus avoiding slippage and vibration. **23**

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PRODUCT PARADE

Jet compressors . . . for mixing gases in desired proportion at LPG-Air gas plants and in other peak shaving operations . . . are described in new bulletin from Schutte and Koerting Co. New 16-page bulletin details construction, operation, and application information on fixed-nozzle, manually-controlled spindle, and automatically controlled spindle types. Also includes nomograph to determine possible weight ratio of secondary gas to primary gas, and a second nomograph to determine compressor size. **24**

New field regulator booklet . . . published by Reynolds Gas Regulator Co. . . . outlines features of entire line of Reynolds high pressure field gas regulators. Part of a current catalog revision, the 8-page booklet contains complete information on high pressure, intermediate, and field regulators. Models include Series 8250, 8525, and 8550. All are springloaded for psi to psi regulation. **25**

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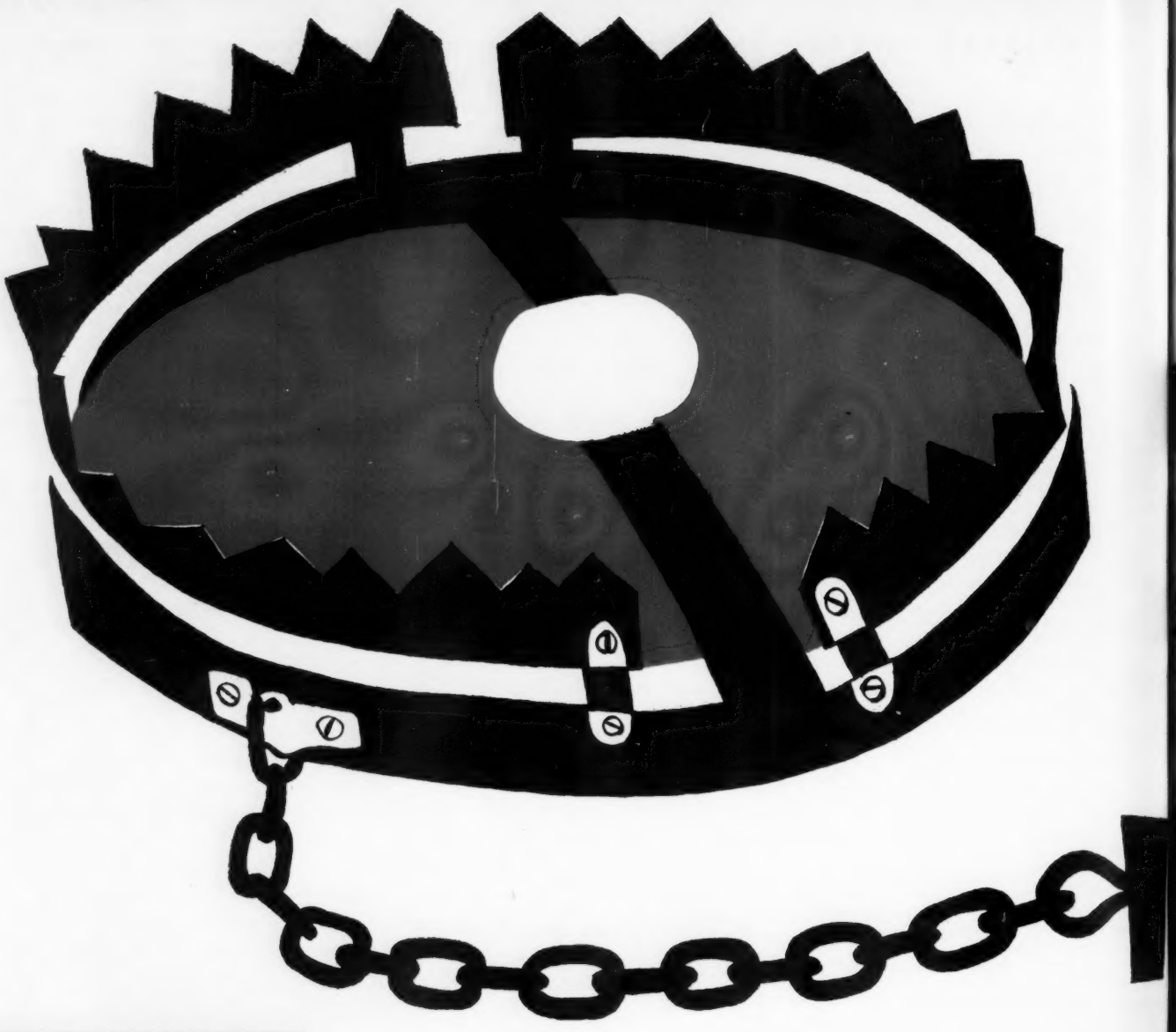

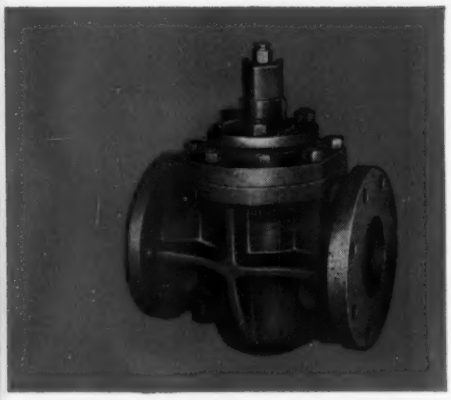

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